GEOLOGY LIBRARY
Science
qQE
125
.A12
7:1

Cat

GEOLOGICAL SURVEY OF MICHIGAN
ALFRED C. LANE, STATE GEOLOGIST

VOL. VII
PART I

GEOLOGICAL REPORT

ON

MONROE COUNTY
MICHIGAN

BY

W. H. SHERZER

ACCOMPANIED BY SEVENTEEN PLATES AND EIGHT FIGURES INCLUDING THREE COLORED MAPS

PUBLISHED BY AUTHORITY OF THE LAWS OF
MICHIGAN
UNDER THE DIRECTION OF
THE BOARD OF GEOLOGICAL SURVEY

LANSING
ROBERT SMITH PRINTING CO., STATE PRINTERS AND BINDERS
1900

DOUGLAS HOUHTON, State Geologist.

Reports from 1838-1846 were published with Legislative documents as follows: S. D. means Senate document; H. D., House document; J. D., joint document. State Geologist is abbreviated S. G., and State Geological Survey, S. G. S.

1838. Report of a select committee of the Board of Regents of the University on the collection of the S. G.
H. D. Vol. I, p. 1-2; S. D. No. 1, p. 1. H. D. No. 55 is duplicate of No. 1.
Statement of the expenditures on account of the S. G. S. for the year 1837.
H. D. No. 8, pp. 115-118; S. D. No. 21 (First annual account of the S. G.), pp. 315-318.
Report of the S. G. (first annual).
H. D. No. 24, pp. 276-317; S. D. No. 16; separately, No. 14, pp. 1-39.
Communication from the S. G.
H. D. No. 46, pp. 547-460.

1839. Report of the S. G. in relation to the improvement of State Salt Springs.
H. D. No. 2, pp. 39-45; S. D. No. 2, pp. 1-8.
Report of the committee on the S. G.'s report in relation to the improvement of the State Salt Spring.
H. D. No. 4, pp. 123.
Report of the S. G. in relation to the iron ore, etc., on the school section in town five south, range seven west, in Branch county.
H. D. No. 21, pp. 342-344.
Second annual report of the State Geologist.
H. D. No. 23, pp. 380-507; S. D. No. 12, pp. 264-391; also separately H. R. No. 23, and S. R. sometimes misprinted No. 13 and No. 23, pp. 39 and appendix of subreports 123 pp.
Report of the Committee of the Senate on Manufactures, to whom was referred the communication of the S. G. relative to salt springs and the salines of the State.
S. D. No. 3, pp. 85-86 (parallel to H. D. No. 4).
Communication from the S. G. relative to the G. S.
S. D. No. 25, pp. 463-466; J. D. No. 3, pp.

1840. Report of S. G. relative to the improvement of the salt springs.
H. D. No. 2, Vol. I, pp. 18-23; S. D. No. 8, Vol. II, pp. 153-158.
Annual report of the State Geologist (third, map of Wayne county).
H. D. No. 27, Vol. II, pp. 206-293; S. D. No. 7, Vol. 2, pp. 66-153; separately, H. R. No. 8, pp. 1-124.
Report of the select committee to whom was referred the several reports of the S. G.
H. D. No. 46, Vol. II, pp. 455-461.
Report of the majority of the Committee of Finance on the communication and accounts of the S. G. for 1839.
Report of the minority of the Committee on Finance on the same subject.
Report of the select committee on S. G.'s report and accounts relative to improvement of Salt Springs, etc.
S. G.'s account for the year 1839, the same being the subject matter of the three preceding reports.
S. D. No. 15, 16, 17, 18, pp. 209-224.

1841. Special message concerning state salt springs.
H. S. and J. D. No. 5, pp. 235-254.
Annual report of the S. G. (fourth).
H. S. and J. D. No. 11, pp. 472-607; separately H. D. No. 27, pp. 1-184; S. D. No. 16, pp. 1-184.

1841. Report of the S. G. relative to county state maps.
H. D. No. 35, pp. 94-98.

1842. Report of the S. G. relative to the State Salt Springs.
H. D. No. 2, pp. 15-21; S. D. No. 1, pp. 1-9.
Report of the select committee in relation to the report of the S. G.
H. D. No. 19, pp. 77-79.
Annual report of the S. G. (fifth).
H. D. No. 14, p. 6; J. D. No. 9, pp. 436-441.

1843. Annual report of S. G. (sixth).
H. D., S. D., and J. D. No. 8, pp. 398-402.
Report of the S. G. relative to the State Salt Springs.
S. D. No. 9, pp. 402-408.

1844. Annual report of the S. G. (seventh).
S. D. No. 11 (three pages).
Maps of Washtenaw, Calhoun, Jackson and Lenawee counties were published separately.

1846. Report from Geological Department by S. W. Higgins, principal assistant.
J. D. No. 12, 22 pp.
Report of the joint committee relative to the Geological Survey.
J. D. No. 15, 8 pages.
D. Houghton undertook an arrangement with the Linear Survey of the U. S. Land Office by which a certain amount of geological work was done, which was never published by the State, the results of which appear largely in the township plats of the Land Office, and in the report of C. T. Jackson, 1849, U. S. S. Ex. Doc. No. 1, pp. 371-935, H. Ex. Doc. No. 5, Vol. 3, Part 3, including sub-reports of W. A. Burt and Bela Hubbard on the geology of the subdivisions of the Linear Survey, First Session 31st Congress, and of Foster & Whitney, U. S. Geologists, Part I, H. Ex. D. No. 69, pp. 1-224 and 12 Plates, First Session 31st Congress; S. Ex. D. No. 2, Vol. 2, p. 147, Second Session 31st Congress; Part II S. Ex. D. No. 4, Vol. 3, p. 3, Special Session 32d Congress.

We may add as containing work done under the S. G. S.:

Reports on the Mineral Region of Lake Superior, with a correct map of the same and a chart of Lake Superior (first title page). Reports of Wm. A. Burt and Bela Hubbard, Esqs., on the geography, topography and geology of the U. S. Surveys of the Mineral Region of the South Shore of Lake Superior, for 1845: By J. Houghton, Jr., and T. W. Bristol, Detroit, 1846 (second title page).

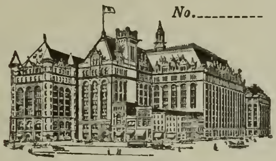
A second edition was published the same year in Buffalo by J. Houghton, Jr., the title being "The Mineral Region of Lake Superior."

The "Memoir of Douglas Houghton," by Alva Bradish, Detroit, 1889, which reprints the early reports almost in full.

A. WINCHELL, State Geologist.

1861. First biennial report of the progress of the G. S. of M. Embracing observations on the Geology, Zoology and Botany of the Lower Peninsula. Made to the Governor Dec. 31, 1860.
The Walling Tackabury State Atlas contains a paper with geological and topographic maps by A. Winchell, reprinted separately under the title "Michigan."

1869. Report of the Joint Committees on Geological Survey, made to the Legislature of Michigan, Lansing,

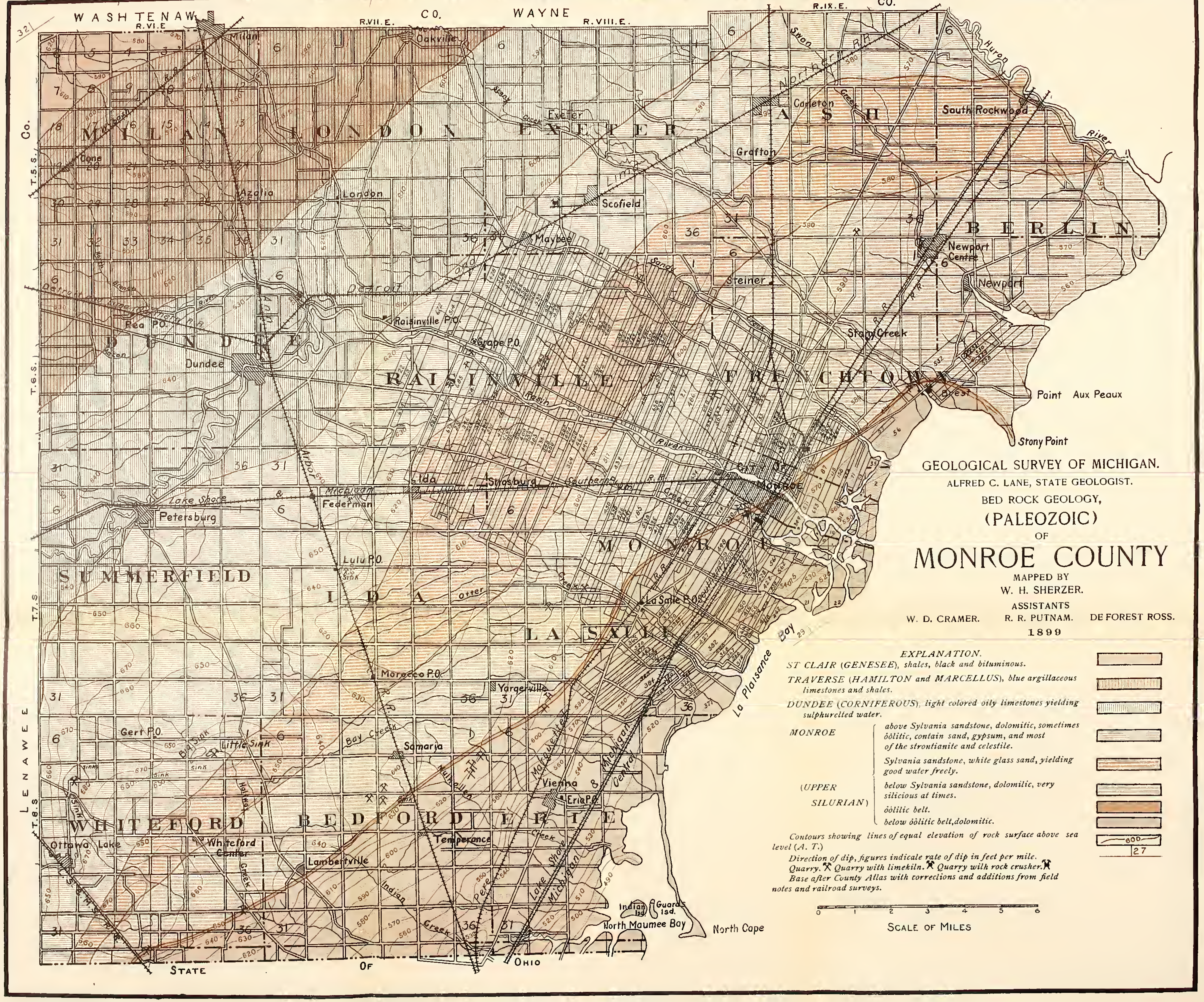


No._________

LIBRARY OF THE
PRUDENTIAL INS. CO. OF AMERICA
NEWARK, N. J.
STATISTICIAN'S DEPARTMENT

Section __________________________
Subject__________________________
Date Recd._______________________
Acknowledged ____________________
Indexed __________________________

COMB 8005 10-3-19



GEOLOGICAL SURVEY OF MICHIGAN.
ALFRED C. LANE, STATE GEOLOGIST.
BED ROCK GEOLOGY,

(PALEOZOIC)
OF
MONROE COUNTY

MAPPED BY
W. H. SHERZER.
ASSISTANTS
W. D. CRAMER. R. R. PUTNAM. DE FOREST ROSS.
1899

EXPLANATION.

ST CLAIR (GENESEE), shales, black and bituminous. ▭

TRAVERSE (HAMILTON and MARCELLUS), blue argillaceous limestones and shales. ▭

DUNDEE (CORNIFEROUS), light colored oily limestones yielding sulphuretted water. ▭

MONROE (UPPER SILURIAN)
- *above Sylvania sandstone, dolomitic, sometimes ôölitic, contain sand, gypsum, and most of the strontianite and celestite.* ▭
- *Sylvania sandstone, white glass sand, yielding good water freely.* ▭
- *below Sylvania sandstone, dolomitic, very silicious at times.* ▭
- *ôölitic belt.* ▭
- *below ôölitic belt, dolomitic.* ▭

Contours showing lines of equal elevation of rock surface above sea level (A. T.) 600

Direction of dip, figures indicate rate of dip in feet per mile. 27

Quarry. ⚒ *Quarry with limekiln.* ⚒ *Quarry with rock crusher.* ⚒

Base after County Atlas with corrections and additions from field notes and railroad surveys.

0 1 2 3 4 5 6

SCALE OF MILES

PROPERTY OF THE
PRUDENTIAL INS. CO

GEOLOGICAL SURVEY OF MICHIGAN

ALFRED C. LANE, STATE GEOLOGIST

VOL. VII

PART I

GEOLOGICAL REPORT

ON

MONROE COUNTY

MICHIGAN

BY

W. H. SHERZER

ACCOMPANIED BY SEVENTEEN PLATES AND EIGHT FIGURES INCLUDING
THREE COLORED MAPS

PUBLISHED BY AUTHORITY OF THE LAWS OF
MICHIGAN
UNDER THE DIRECTION OF
THE BOARD OF GEOLOGICAL SURVEY

WISCONSIN
HISTORICAL
SOCIETY

LANSING
ROBERT SMITH PRINTING CO., STATE PRINTERS AND BINDERS
1900

Entered according to Act of Congress in the year 1900, by

Governor Hazen S. Pingree

for the State of Michigan, in the Office of the Librarian of Congress, Washington.

GEOLOGY LIBRARY

QE
125
A12
(7pt.1)

OFFICE OF THE STATE GEOLOGICAL SURVEY,
LANSING, MICH., June 21, 1900.

To the Honorable, the Board of Geological Survey of Michigan:

HON. HAZEN S. PINGREE, *President.*
HON. PERRY F. POWERS.
HON. JASON E. HAMMOND, *Secretary.*

GENTLEMEN—Herewith I transmit the Report, maps and illustrations of the report on Monroe county prepared by Prof. W. H. Sherzer, the issue of which, as Part I of Vol. VII, you have authorized. Five hundred copies as you have voted are issued separately, while the remainder of the edition is reserved to be bound up with the remaining parts, upon which the printer is now at work. This and the following report upon Huron county are of rather exceptional size, because the two counties themselves are of exceptional geological interest. They have more than usually numerous rock exposures, and taken together, they cover pretty fairly the whole variety of rocks and surface conditions in the Lower Peninsula. Thus dwellers in the other counties thereof will find much information which they can apply to their own homes.

Some of the valuable results of Prof. Sherzer's work are: the description of the considerable thickness and extent of the Sylvania glass-sand, a work of great value to a State so exceptionally well situated for glass manufacture as Michigan; the description of the deposits of high grade limestone and strontianite, both of which may be important factors in beet-sugar manufacture, while the former is also in great demand for the manufacture of soda ash; and the determination of the limited extent and economic value of the oil and gas. The professional geologist will appreciate the light thrown on the Helderberg question, and on the detailed history of the Great Lakes.

With great respect, I am your obedient servant,

ALFRED C. LANE,
State Geologist.

TABLE OF CONTENTS.

CHAPTER I.

GEOGRAPHICAL AND HISTORICAL INTRODUCTION.

A. Geographical:

Page.
§ 1. Location 1
§ 2. Railroads 1
§ 3. Proposed lines 2
§ 4. Miscellaneous data 3

B. Historical:

§ 5. Early boundaries 3
§ 6. Indian occupation 5
§ 7. Early settlements 6
§ 8. War of 1812 6
§ 9. Growth of population 7
§ 10. Southern boundary 7

C. Geological Work in the County:

§ 11. Previous work 9
§ 12. Houghton survey 9
§ 13. Winchell survey 12
§ 14. Rominger survey 14
§ 15. Work of present survey 15
§ 16. Acknowledgments 16

CHAPTER II.

DEVONIAN AND QUATERNARY.

A. Quaternary Deposits:

§ 1. Thickness 18
§ 2. General nature 19
§ 3. Boulders 20
§ 4. Post-glacial deposits 24

B. Devonian Formations.—St. Clair (Genesee) Shales:

§ 5. General arrangement of Devonian formations 25
§ 6. Name 25
§ 7. General data 25
§ 8. Thickness 26
§ 9. Lithological character 26
§ 10. Geological position 27
§ 11. Lithological history 29

C. Traverse (Hamilton) Group:

§ 12. Name and geological position 31
§ 13. General data 31
§ 14. Thickness 32
§ 15. Lithological characters 32
§ 16. Lithological history 35

D. Dundee Limestone:

Page.
§ 17. Name and geological position 35
§ 18. General data 37
§ 19. Drift covering 38
§ 20. Thickness 38
§ 21. Lithological characters 38
§ 22. Lithological history 40

CHAPTER III.

SULURIAN FORMATIONS.

A. Monroe Beds:

§ 1. Name and geological position 43
§ 2. General data 44
§ 3. Thickness 45
§ 4. Lithological characters 46
§ 5. Lithological history 48

Description of Special Beds:

§ 6. Sylvania sandstone 53
§ 7. Oölitic beds 60

B. Beds reached by Borings:

§ 8. Deep well records 66
§ 9. Interpretation of records 73

CHAPTER IV.

QUARRIES.

A. Dundee Formation:

§ 1. Macon quarry 75
§ 2. Dundee quarry 77
§ 3. Petersburg excavations 78

B. Monroe Beds:

a. Quarries above the Sylvania sandstone:

§ 4. Woolmith quarries 78
§ 5. Raisinville quarries 82
§ 6. Ida quarries 85
§ 7. Lulu quarry 87
§ 8. Little Sink quarry 88
§ 9. Ottawa Lake quarries 89

b. Quarries below the Sylvania sandstone:

§ 10. Newport quarries 92
§ 11. Frenchtown quarries 93
§ 12. Monroe quarries 95
§ 13. La Salle quarries 97
§ 14. Bedford quarries 98
§ 15. Whiteford quarries 100

CHAPTER V.

PHYSICAL GEOGRAPHY.

§ 1. Climate 101
§ 2. General configuration of the county 105
§ 3. Elevations within the county 106
  a. U. S. survey levels 106
  b. Railroad levels 107
  c. Elevated beach levels 109
  d. Aneroid levels 109
§ 4. Surface drainage 109
§ 5. Underground drainage 114
§ 6. Diagonal features 118

CHAPTER VI.

THE GLACIAL EPOCH IN SOUTHEASTERN MICHIGAN.

A. Rock Surface Topography: Page.

§ 1. Introduction 121
§ 2. Traverse valley 122
§ 3. Dundee valley 122
§ 4. Sylvania valley 123
§ 5. Erie trough 124

B. The Ice Invasion:

§ 6. The early ice sheets 124
§ 7. The Wisconsin ice sheet 126
§ 8. Rock scorings 128

C. Lacustrine stages:

§ 9. Introduction 132
§ 10. Lake Maumee 133
  a. Van Wert stage 133
  b. Leipsic stage 135
§ 11. Lake Whittlesey 135
§ 12. Arkona beach 138
§ 13. Lake Warren 140
  a. Forest stage 140
  b. Grassmere stage 141
§ 14. Lake Erie 144
§ 15. Recent submergence 145

D. Post-glacial warping:

§ 16. Recent production of stony ridge 147

CHAPTER VII.

SOILS AND SUBSOILS.

A. Nature, Origin and Varieties:

§ 1. Preglacial soils 149
§ 2. Glacial subsoils 151
§ 3. Post-glacial soils 153
  a. Sand and gravel 153
  b. Clay 154
  c. Loam 155
  d. Silt 155
  e. Muck 156

B. Relation of Soils to Vegetation:

§ 4. Fertility 157
§ 5. Fruit culture 160
§ 6. Farm products 161
§ 7. Forest growth 164

C. Amelioration of Soils:

§ 8. Importance of subject 165
§ 9. Natural amelioration 166
  a. Inorganic agencies 166
  b. Organic agencies 168
§ 10. Artificial amelioration 171

CHAPTER VIII.

ECONOMIC PRODUCTS.

§ 1. Building materials 174
§ 2. Quick lime 175
§ 3. Soda ash limestone 177
§ 4. Beet sugar limestone 178

Page.
§ 5. Cement materials 180
§ 6. Road metal 183
§ 7. Glass sand rock 186
§ 8. Brick and tile 187
§ 9. Natural gas and oil 190
§ 10. Artesian water and mineral springs 194
§ 11. Marl 200
§ 12. Salt 201

CHAPTER IX.

MINERALS OF MONROE COUNTY.

A. Carbonates:

§ 1. Introduction 203
§ 2. Calcite 203
§ 3. Aragonite 204
§ 4. Tufa 205
§ 5. Dolomite 206
§ 6. Strontianite 206

B. Sulphates:

§ 7. Celestite 208
§ 8. Gypsum 209
§ 9. Anhydrite 210
§ 10. Epsomite 210

C. Chlorides:

§ 11. Halite 211

D. Sulphur and Sulphides:

§ 12. Sulphur 212
§ 13. Pyrite and marcasite 213

E. Oxides:

§ 14. Bog iron ore 214
§ 15. Crystallized quartz 215
§ 16. Chert 216

F. Phosphates:

§ 17. Apatite 217

G. Hydrocarbons:

§ 18. Asphaltum 217
§ 19. Key to minerals 218

CHAPTER X.

FOSSILS OF MONROE COUNTY.

§ 1. General nature of fossils 220
§ 2. Conditions of preservation 221
§ 3. Fossils of the Monroe beds 222
§ 4. Fossils of the Dundee formation 226

LIST OF ILLUSTRATIONS.

PLATES.

Page.
I. Map of Paleozoic Geology .... faces
II. South wall of the Woolmith quarry, showing massive building blocks of the silicious dolomite .... p. 80
III. View of the Cummins quarry, locally known as the "Little Sink." Observe the scanty soil and stunted forest growth .... p. 88
IV. Quarry floor, west wall and crusher of the Monroe Stone Company p. 96
V. Section of the Monroe well (from Vol. V.) .... p. 100
VI. Cross sections along line of railroads .... p. 105
VII. Map of Surface Geology .... p. 112
VIII. View of the River Raisin at Monroe, showing the typical beds of dolomite .... p. 113
IX. Rock opening through which the water of the "Big Sink" escapes. View looking into the bottom of a small ravine .... p. 116
X. Bed of Ottawa Lake sink, from the head looking southward. Oct. 15th, 1898 .... p. 118
XI. Sand ridge of lower beach west of Erie, showing typical growth of oak and evergreen. Dec. 4, 1897 .... p. 120
XII. View of Stony Point looking northeastward toward Point aux Peaux. Observe the ice polished and battered condition of the rock in the foreground .... p. 128
XIII. Roadway through one of the Monroe nurseries, showing a typical wave washed flat .... p. 140
XIV. Outcrops of the "Monroe beds" at Point aux Peaux, Lake Erie...... p. 144
XV. Map, contours showing depth of drift, oil and gas and artesian belts, etc., also indicated .... p. 192
XVI. Site of the "Shawnee Spring" near Monroe. The extensive mound built up by the spring is but faintly shown in the field beyond the picket fence .... p. 198
XVII. Waterlime Fossils, reprinted from Annals N. Y. Acad. Sciences, Vol. V, Pl. V, Ohio Geol. Survey, Second Ann. Report and Vol. VII, Plate I.. 242

FIGURES.

1. Mammoth boulder transported by the ice sheet and dropped east of the site of Ida. Four feet above ground; twenty feet long 21
2. The "Big Sink" doing service as a lake, March 26, 1898........................ 115
3. The "Big Sink" under cultivation, Oct. 15, 1898................................ 115
4. View of the government canal, near Monroe, opening into Lake Erie.. The view gives one an idea of the inundated "drowned" appearance near their mouths of all streams which empty into Lake Erie............ 146
5. Lotus bed in the marsh near Monroe. The marsh is due to recent submergence by the Lake. Photographed, August, 1890 148
6. View of extensive Cranberry marsh when flooded in the spring. Sec. 24, Summerfield township 157

Page.
7. Gushing well struck upon Otter Creek, Sept., 1899. Residence of Edward Sharkey, 2½ miles southeast of La Salle.......... 197
8. Great Sulphur spring in the lake marsh near Erie. The figure gives also a view of the inundated margin; cf. Fig. 5.......... 199

TABLES.

I. Statistical data of Monroe Co., Michigan 4
II. Annual Climatic data, Grape, Monroe Co., Michigan.......... 102
III. Annual Climatic data, Toledo, Ohio 103
IV. Average Monthly Temperature and Precipitation, 1871-1899.......... 104
V. Annual Climatic data Toledo, 1860-1869.......... 104
VI. Altitudes of Railroad stations 108
VII. Glacial striæ in Monroe Co.......... 131
VIII. Former Lake Beaches in Monroe Co.......... 143
IX. Percentage Composition of Air Dry Farm Products.......... 159
X. Bushels of Fruit Produced in 1898 161
XI. Monroe Co. Farm Products for 1898 162
XII. Composition of Limestone found suitable for Beet Sugar Manufacture.. 179
XIII. Composition of American Cement Rocks 181
XIV. Composition of English Portland Cement.......... 182
XV. Key to the Minerals of Monroe 219

ERRATA.

Page 129, line 9 from bottom, for Chamberlain read Chamberlin.
Page 181, Table XII should be Table XIII.
Page 199, line 4, for Cushino read Cousino.
Page 219, Table XIV should be Table XV.

CHAPTER I.

INTRODUCTION.

A. *Geographical.*

§ 1. Location.

The county which constitutes the subject of this report occupies the extreme southeastern corner of the lower peninsula of Michigan. To the north are Wayne and Washtenaw counties, to the west Lenawee county; Lucas county of the state of Ohio, forms the southern boundary while the eastern is formed almost entirely by Lake Erie. The county covers about 560 square miles, distributed over fifteen townships between 41° 44′ and 42° 6′, north latitude; and between 83° 11′ and 83° 46′, west longitude.*

§ 2. Railroads.

Eight lines of railroads intersect the county in all directions and no portion of it is beyond the sound of their heavily loaded trains. Parallel with the lake shore and back from it from one to five miles, the Michigan Central and Lake Shore traverse the county in a northeast and southwest direction. To the west the Pere Marquette enters from the north, swings to the southwest near Monroe and passes into Ohio about a mile west of the two preceding roads. The Detroit and Lima Northern enters the county from the west, from Dundee turns northeastward, crossing the Pere Marquette at Carleton and enters Wayne county at the northeastern corner of Ash township. Having the same general direction as all of the preceding and the common purpose of centering in Detroit, a branch of the Wabash grazes the northwestern corner of the county.

---

*The exact location of points somewhat near the four boundaries of the county, as determined by the government engineers, is as follows:

	Latitude N.	Longitude W.
Gibraltar lighthouse	42° 05′ 25.90″	83° 11′ 14.80″
Turtle Island lighthouse	41° 45′ 08.80″	83° 23′ 28.80″
Monroe lighthouse	41° 53′ 27.70″	83° 19′ 53.20″
Triangulation Station near Dundee	41° 55′ 28.08″	83° 40′ 13.93″

Heading for Toledo, the Ann Arbor gives a nearly complete northwest and southeast section of the county through Milan and Dundee to Alexis junction with the Pere Marquette. Nearly parallel with it the Toledo-Adrian branch of the Lake Shore cuts the extreme southwestern corner of the county. The only east and west road within the limits of Monroe county is the Monroe-Adrian branch of the Lake Shore, passing through Petersburg. These last two branches of the Lake Shore system are of historic interest since they were the first railroads in the northwest. The Toledo-Adrian road was originally built by private enterprise in 1836 and was known as the Erie and Kalamazoo railroad. For about a year the cars were drawn by horses over wooden rails, when the "strap rail" was laid and the first locomotive introduced. The road from Monroe to Adrian was constructed in 1839 by the then infant State of Michigan for the purpose of opening up the interior and was operated by it until 1846, when it was sold to the Michigan Southern Railroad Company.

§ 3. Proposed lines.

During the summer of 1899 the bed for a new road from Toledo to Detroit was in process of construction, lying between the Michigan Central and Lake Erie, to be known as the Detroit and Toledo Shore Line. The grading from Toledo to Monroe is well advanced and will probably be completed within the limits of the county during the coming summer. By closely hugging the shore of the lake and of Detroit River it is claimed that the distance between Detroit and Toledo will be materially lessened. An electric road intended to connect these two cities awaits completion. The grading from Erie to Monroe is practically done, following throughout the greater part of the distance the main highway, and a power house has been constructed in Monroe. The franchises have been secured for an electric road from Ypsilanti to Milan which it is expected will be continued to Adrian, thus crossing Milan township. It is reported to be the intention of the promoters of this road to construct a line from Milan, through Dundee, to Toledo. Still another road, with branches from Ann Arbor and Detroit, is expected to enter the county north of Carleton and to follow the approximate line of the Pere Marquette to Monroe. With such development of steam and electric lines, connected with every farm by means of substantial stone roads; with the private telephone, free rural delivery of mail, and the attendant improvement in educational facilities, the life of the farmer is one to be envied, and the question of keeping the son and daughter upon the farm will be largely settled.

§ 4. Miscellaneous data.

Table I gives an alphabetical list of the townships of the county, their postoffices and some miscellaneous information relating to them, gathered from latest available sources. It shows the population in 1894 to have been 33,181. The city of Monroe is the county seat, having in 1894, a population of 5,613. There are three incorporated villages, namely: Dundee, 1,115; Petersburg, 446; and Milan, 964.

B. Historical.

§ 5. Early boundaries.

Early in the century just closing, "Wayne County" comprised the entire lower peninsula of Michigan, a part of the upper peninsula as well and adjoining portions of Ohio, Indiana and Wisconsin. From this vast tract Monroe county was set off in 1817, by proclamation of Gen. Lewis Cass, then governor of Michigan Territory; the present Wayne county having been established two years earlier. The original proclamation by which the boundaries of the county were first established is here given.

"WHEREAS, It is considered that the public good will be promoted by the erection of a new county in the said Territory;

Therefore, I do, by virtue of the power and authority in me vested, constitute the whole of that portion of said territory of Michigan which is included within the lines and limits following, that is to say: Beginning at the mouth of the river Huron of Lake Erie, within said territory; thence up the said river in the middle thereof until its intersection with the line between the third and fourth tier of townships south of the "base line," so called; thence due west with the said line until it shall intersect the present Indian boundary line, namely, to the western line of the first range; thence with said line due south to the southern boundary of said territory; thence along the southern boundary thereof, easterly to the southeast corner thereof; thence northerly along the eastern boundary of said territory to a point due east from the place of beginning; thence to the place of beginning; to be and remain henceforward a separate county, to be called the county of Monroe.

* * * * * * * * *

Given under my hand and the great seal of said Territory, at Detroit, this fourteenth day of July, A. D. one thousand eight hundred and seventeen, and in the fortieth year of the Independence of the United States of America.

LEWIS CASS."

An inspection of the present map will show that as thus outlined the county was much larger, upon the north and west particularly. A second proclamation, issued five years later, reduced it to its present limits, but attached to it the county of Lenawee, from which it was separated in 1826.

"The county of Monroe, established by an executive act of July 14, 1817, shall be bounded as follows:

Beginning at the boundary line between the United States and the province of

TABLE I.—*Statistical data of Monroe County, Michigan.*

No.	Township.	Tier south.	Range east.	Population, 1894.	Area in acres Supervisors' assessment, 1896.	Acres in farms. 1898.		Number farms, 1898.	Average size of farms in acres.	Postoffices.
						Improved.	Unimproved.			
1	Ash............	5	ix	2,039	22,485.99	13,818	3,877	251	70	Carleton, Grafton.
2	Bedford........	8 and 9	vii	2,075	25,100.35	15,455	4,153	291	67	Samaria. Temperance, Lambertville.
3	Berlin	5 and 6	ix and x	1,850	22.334.17	7,326	2,387	58	167	South Rockwood. Newport.
4	Dundee.........	6	vi and vii	3,303	29,828.48	20,000	9,000	665	44	Dundee, Rea.
5	Erie	8 and 9	viii	1,476	18,356.15	11,960	505	153	81	Erie.
6	Exeter.........	5	viii	1.912	22,811.79	14,975	4.166	266	72	Exeter, Scofield, Maybee.
7	Frenchtown....	6 and 7	viii, ix, x	1,958	29,425.23	18,629	3,115	261	83	Brest, Steiner.
8	Ida.............	7	vii	1,594	23,409.75	14.768	4.122	261	72	Ida. Lulu. Morocco.
9	LaSalle	7	viii and ix	1.333	16,109.55	12,638	2,307	183	82	LaSalle, Yargerville.
10	London...	5	vii	1,373	22,596.91	10,777	4,480	201	76	London, Oakville.
11	Milan...........	5	vi	2,105	22.506.63	12,239	1.510	161	85	Milan, Azalia, Cone.
12	Monroe.........	6 and 7	viii and ix	6,490	13,271.07	7,328	1,980	116	80	Monroe.
13	Raisinville......	6 and 7	vii and viii	1,775	29,757.34	19,908	3,587	245	96	Strasburg, Raisinville, Grape.
14	Summerfield...	6 and 7	vi	2.038	26,193.68	13,669	5,367	223	85	Petersburg.
15	Whiteford......	8 and 9	vi	1,860	25,984.80	16,455	4,503	291	72	Whiteford Center, Gert, Ottawa Lake.
	Totals.......	5 9	vi-x	33,181	350,171.89	209.945	55,059	3,626	73	33 offices.

Upper Canada, where the southern boundary of the county of Wayne intersects the same, thence with the said southern boundary, west to the mouth of the river Huron of Lake Erie; thence with the said boundary, keeping the middle of said river, to the line between the townships numbered four and five south of the base line; thence west to the line between the fifth and sixth ranges east of the principal meridian; thence south to the line between the Territory of Michigan and the State of Ohio, thence with the said line to the boundary between the United States and the province of Upper Canada; thence with the said boundary line to the place of beginning. * * *

In testimony whereof I have caused these letters to be made patent, and the great seal of the said Territory to be affixed. Given under my hand at Detroit, this tenth day of September, in the year of our Lord one thousand eight hundred and twenty-two, and of the Independence of the United States the forty-seventh.

LEW. CASS.

§ 6. Indian occupation.

The earliest inhabitant, of whom we have any definite traces in southeastern Michigan, was the so called "Mound Builder." If the Palæolithic man of Europe had any representatives in this region his remains and crude implements are yet to be discovered and identified. The tendency of recent investigations of the Ohio and Mississippi valleys is to destroy more and more, the gap between our historic, eastern Indian and the mound building type of savage who depended more upon the soil for his subsistence and defense. It must be admitted, however, that he was intellectually the superior of the Indians who dispossessed him of his fertile fields and drove him, probably southwestward. He cultivated the soil extensively, wove cloth, burned pottery, manufactured a superior stone implement and worked our copper mines for the red metal. For purposes of burial and sacrifice, and apparently for use as signal stations from which messages could be flashed across the country after approved modern methods, he constructed hemispherical and conical mounds of loose earth. Some very interesting mounds of this character along the St. Clair and Detroit rivers were explored thirty years ago by Henry Gillman, of Detroit, and described in publications of the Smithsonian Institution, the American Association for the Advancement of Science, and those of the Michigan Pioneer Society. At favorably located points fortifications were constructed, sometimes of great magnitude, displaying a surprising degree of military skill and testifying to the patience and industry of these people. Two semi-circular structures, now covered by the city of Toledo, were described by G. K. Gilbert, Vol. I, Geological Survey of Ohio, 1873. Although no mounds or fortifications are known within the limits of our county, the characteristic implements are here found, and we are certain that this interesting type of savage man roamed its forests, drank from its clear springs and navigated its waterways. History opens with tribes of the great

Algonkian nation in possession of this region; the Ottawas, Chippewas and Pottawattomies. The Wyandottes, or Hurons of the French, originally dwelt upon the St. Lawrence and are believed to have their descent from the powerful Iroquois of New York. They were, however, attacked by the latter, driven to Michigan and continually persecuted by them, being at one time almost annihilated.

§ 7. Early settlements.

Col. Francis Navarre is credited with being the first white settler within the present limits of Monroe county. He settled in 1780 near the mouth of the River Raisin, known by the Indians as "Namet Cybi," and in 1785 secured from his "Pouteouatamie" friends a deed to a considerable tract of land, lying south of the river, which land is still largely held by his descendants. In 1784 over one hundred families of Canadian French arrived and founded Frenchtown, upon the north bank of the Raisin, opposite Monroe. The same year other French families settled along the creeks to the north and south.

§ 8. War of 1812.

This part of Michigan was a portion of New France up to the year 1763, when it came into possession of the British and was actually held by them until 1796, although nominally transferred to the United States in 1783, at the clase of the Revolution. By Hull's Treaty of Detroit, in 1807, the Indian titles to lands in the county were extinguished, except nine sections of land upon the Macon reserved for the above four tribes. Encouraged by the British these Indians became unfriendly and during the War of 1812, the eastern part of the county became the scene of bloody hostilities. Marching to the relief of Detroit Gen. Winchester, with 1,000 Kentucky troops, was surprised January 22, 1813, by British and Indian allies and suffered a most crushing defeat; nearly all being killed or captured. The scene of the battle and the terrible massacre, was on the banks of the Raisin, about a mile east of the site of Frenchtown, but as the river was frozen it extended southward as far as the poor soldiers succeeded in eluding their savage pursuers. Gen. Winchester, who was spending the night at the cabin of Col. Francis Navarre, was himself captured and taken to Fort Malden, Canada. "Remember the Maine" is but a paraphrase of the Kentuckians' "Remember the Raisin," used later as a battle cry. In 1818 the bones of the unfortunate troops were collected and buried with honors at Detroit in the Protestant burying ground. In 1849 they were transferred, along with others from the battlefield, to Frankfort, Kentucky. The disgraceful surrender of Detroit in August, 1813, was followed within less than a month by the glorious naval victory of Commodore Perry and the stars and stripes again soon floated over the city. Five times had the flag changed within the half century.

§ 9. Growth of population.

These frontier troubles and the malicious report of the government agents in regard to the soil and climate of this portion of the State had much to do in retarding its development. The entire white population of the territory in 1800 was 551, in 1810 but 4,762, of whom nearly one-third were in Monroe county. During the next ten years it increased to 8,896 only, but jumped to 31,639 from 1820 to 1830. In the decade during which the territory acquired statehood, the growth in population was most surprising, reaching 212,267 in 1840. Owing to its fertility, location and natural resources Monroe county had more than its share in this increase. The following table tells the story of its gradual development:

1810— 1,340
1820— 1,831
1830— 3,187
1837—10,611
1840— 9,922
1845—13,861
1850—14,698
1854—18,030
1860—21,593
1864—22,221
1870—27,475
1874—30,111
1880—33,624
1884—33,353
1890—32,337
1894—33,181

§ 10. Southern boundary.

Before the present boundaries of the county were finally established the question of the line between the State of Ohio and Michigan Territory had first to be settled and this brought on the temporary turmoil, known as the "Toledo War." The celebrated "Ordinance of 1787," by which the Northwest Territory was organized, provided that the boundaries should be altered "so as to form one or two states in that of the said territory which lies north of an east and west line drawn through the southerly bend, or extreme of Lake Michigan." The map which was then regarded as official was the "Mitchell map," published in 1755 before any accurate survey of the lake had been made, and this map represented Lake Michigan as terminating at latitude 42° 20′ N. This line passes through the city of Detroit and if the apparent intention of the framers of the ordinance had been carried out the writing of the geological history of Monroe county would have been done by the Ohio Survey. It was ascertained later that Lake Michigan extended much further south and that this east and west line would somewhere strike the western or southern shore of Lake Erie. The act of the Senate and House of Representatives of 1802, authorizing the State of Ohio to form a constitution and state government, placed the boundary "on the north by an east and west line drawn through the southerly extreme of Lake Michigan, running east, after intersecting the due north line aforesaid, from the mouth of the Great Miami, until it shall intersect Lake Erie, or the territorial line, and thence, with the same, through Lake Erie, to the Pennsylvania line aforesaid." The constitution of Ohio provided, however, that if this line should intersect Lake Erie east of the mouth of the Miami of the Lake (Maumee), then the northern boundary should be a line run direct from the southern extreme of Lake Michigan to the most northerly cape of the Miami (Maumee) Bay. The acceptance of the Ohio constitution, containing this clause, was regarded by the State as authorizing this boundary line, although not so regarded by Congress itself. This line was run in 1817 by surveyor Harris and was known as the "Harris Line." The line claimed by Michigan, namely, that drawn due east from the southerly extreme of Lake Michigan, was known as the "Fulton Line" and between them there was included the strip of land in dispute five miles broad at the west, eight miles broad at Lake Erie and about seventy miles long.. Perhaps no serious differences would have occurred between the territory and state if the Erie canal from Cincinnati had not been headed for Toledo, which it would make its northern terminus with all the supposed advantages only on condition that it was a part of Ohio. The attempt to re-mark the Harris Line in 1835 precipitated trouble, the militia from each section being called out and brought almost face to face with one another. Michigan was, however, applying for admission to the union of states and was compelled by Congress to accept as its southern boundary the line claimed by Ohio. This it did most reluctantly and was given as a reward to soothe ruffled feelings, the entire upper peninsula.

C. Geological Work within the County.

§ 11. Previous work.

Nothing in the way of systematic geological exploration was attempted in the region covered by this report so long as Michigan remained a territory. Something was known, however, of its natural resources and the pioneers and traders had begun to utilize its economic products. The principal limestone outcrops had been located and rock removed for lime and building purposes. Quarries had been opened in the Raisin bed at Monroe and Dundee, also in the beds of Swan, Stony, Plum and Bay creeks, upon the Macon and at the head of Ottawa lake. In the region of the natural outcrops, particularly upon the "ridge," stone had been superficially quarried. Lime had been burned upon Plum Creek, at Ottawa Lake and at the Macon quarries. The bed of glass sand seven miles northwest of Monroe had been opened and found to produce a good quality of glass. Brick had been burned at Newport, Brest, Dundee and in London township, upon the Saline. The salt springs along the latter stream were known and utilized in an early day by both Indians and settlers.

§ 12. Houghton survey.

Upon the acquisition of statehood Michigan immediately established a "Geological Survey," the act of the Legislature being approved by Gov. Mason, February 23, 1837. Dr. Douglass Houghton was appointed State Geologist, with Bela Hubbard and C. C. Douglass, Assistant Geologists, and S. W. Higgins, topographer and draughtsman. During the summer following a hasty examination was made of the county by Dr. Houghton, having chiefly for its object "the determination of the rock formations, their extent and order of superposition." Under the head of the "Grey Limestone" he speaks of its outcropping edge as extending from the rapids of the Maumee to those of the Raisin, "which may without doubt, be considered identical with the mountain limestone of European geologists."*

The silicious nature of the limestone encountered in ascending the Raisin was noted and from such beds the glass sand layer was stated to have been derived by disintegration. Calcite, as "hog tooth spar" was observed at Monroe; celestite and tremolite (strontianite?) at

---

*1838. Report of the S. G. (first annual.) H. D. No. 24, pp. 276-317; separately, No. 14, pp. 1-39; p. 7.

Brest. The deposits of marl and the mineral springs to the south of Monroe were briefly described. Brine was stated as occurring north of a line drawn from Monroe to Granville, Kent county, which line strikes across the county just south of its northwest corner. As an appendix to his first report, Dr. Houghton published a series of suggestions to those residents disposed to assist in the work (In Senate, February 1, 1838), and 115 questions pertaining to the bed rock, soils, water supply, subterranean forests, peat, marl, iron ore, streams, lakes and surface boulders.

The detailed study of Monroe county was assigned to the assistant Bela Hubbard and was reported upon in the Second Annual Report, February 4, 1839.*

The general topography of the surface, its springs and streams, the soils, subsoils, and timber were studied and described. The natural and artificial rock exposures were visited and the strata determined to be dipping northwest, or northwest by north, at an angle of about 5°. This dip was afterwards† lessened to 15 feet to the mile, but found to vary from 10 to 20 feet.

No attempt was first made at the correlation of these strata with one another, or with those of other regions. Beds of peat and marl were located and their use in the amelioration of the natural soils repeatedly emphasized in the reports. The "Lake ridge," which cuts across the northwestern corner of the county, extending for many miles in either direction, was correctly interpreted as marking the former extension of the lakes. The abrupt change which here occurs in the topography, as well as in the character of the soil and the timber was noted and clearly understood. The surface boulders were termed "erratics" and were recognized as having been transported by some imperfectly understood agency from the north. The surface scratches upon the limerock at Brest and Point aux Peaux were measured and found to be N. 50° E., N. 60° E., N. 65° W. They were ascribed to the "attrition of hard bodies moving in a strong current," (p. 113). In the same report (Second, p. 65), Higgins announces the completion of his topographic map of the county, but if it was ever published all trace of it seems to have been lost. It was very probably similar to his map of Wayne county which appeared the next year in the Third Annual Report.‡

---

*Second annual report of the State Geologist. H. D. No. 23, pp. 380-507; S. D. No. 12, pp. 264-391.

†Fourth Annual Report, p. 135; H. S. and J. D. No. 11, pp. 472-607, separately H. D. No. 27, pp. 1-184; p. 135.

‡Annual report of the State Geologist (third, map of Wayne county); H. D. No. 27, Vol. II, pp. 206-293; S. D. No. 7, Vol. II, pp. 66-153, separately No. 8, pp. 1-120.

A still more detailed study of the geological features of the county was made by Hubbard and further reported upon in the Third Report, above referred to. The limestone was stated to occupy a horizon higher geologically than the blue limestones and shales of Cincinnati (Hudson River Group), but to be below the "black strata" (St. Clair shale), and without doubt is equivalent in position to the "Cliff limestone," of Indiana (p. 83). Three belts of rock, with quarries and outcrops, were recognized as crossing the county in a northeast and southwest direction. The most easterly, and consequently the oldest, is described as a compact limerock, light gray to blue in color, sometimes veined, sometimes oölitic, and carrying distinctive fossils. The most westerly range, highest both topographically and geologically, is somewhat sparry, geodiferous and bituminous, carrying some fossils of a different species from the former. The middle range consists of highly silicious rock, passing into pure sandstone. The individual grains of the glass sand he recognized as consisting largely of perfect quartz crystals. The term "diluvium," or "diluvion" was applied to what is now known as the "drift," made up of "detritus of the upper portion of our coal series, which has been broken up and washed away, and in part of sands and fragments of the primary rocks, transported from a more northerly region." (p. 83). The following, quoted from page 89 of this report, is of interest since it furnishes a clear, concise statement of the views held sixty years ago, and not yet entirely discarded, concerning the origin of this "diluvium."

> "It has been already remarked that in general all the rocks are covered with a mantle of clays, fine detritus of the lime and sand rocks, or loose water-worn fragments of still older rocks, swept from the north by the currents of a universal ocean and deposited during the general subsidence. Some evidences of the direction of these currents were noticed in my report of last year. Among these are the diluvial furrows and scratches on the surface of the limerock. the appearance and direction of which correspond with observations made in some of the more eastern states."

Allusion is made in the next report (Fourth p. 116), to Lyell's iceberg theory, as though the above explanation was not entirely satisfactory. In discussing the origin of the erratics he remarks that they came from the north "Whatever may have been the causes which swept these materials over the face of the rocks, whether oceanic currents or bodies of *floating ice*."

Owing to the inaccessibility of the reports of this first geological survey Hubbard is not generally credited with the work which he did in the way of deciphering, at this early day, the history of our great lakes. Mention will be made of this again in connection with the glacial history of the county. The deposits from the ancient bodies of water he termed "alluvions" to distinguish them from the "diluvion" described above, and "ancient alluvions" to distinguish them from the "recent alluvions," now forming, or having been very recently formed, as marl, peat and bog ore. The "Tertiary clays" (till) were regarded as present in Monroe and Wayne counties, as well as over two-thirds of the lower peninsula. In the Fourth Report (p. 109) Douglass identifies certain limestones in the northern part of the peninsula as Corniferous, and correlates them provisionally with those of Monguagon (Trenton) and hence also with those on the Macon. The geological formations identified and differentiated by this survey, so far as Monroe county is concerned, are shown below.

6. Recent Alluvions.
5. Ancient Alluvions.
4. Diluviums, or Erratic block group.
3. Tertiary clays.
2. Black aluminous slate.
1. Limerocks of Lake Erie.
    c. Corniferous.
    b. Silicious limestones, passing into sand.
    a. Compact gray or blue limestone.

§ 13. Winchell Survey.

With the accidental drowning of Dr. Houghton in Lake Superior, October 13, 1845, further geological work ceased in this region and was not resumed again until the Second Geological Survey was organized by Dr. Alexander Winchell in 1859. In the meantime new outcrops had been discovered, new quarries had been opened and old ones deepened. Many wells had penetrated to the rocks, giving information in regard to the surface deposits and in regard to the rocks themselves. Much geological and palæontological work had been done in New York, and Canada, calculated to throw light upon Michigan geology. Dr. Winchell began his field work in May, 1859, with a re-examination of Monroe county, assisted by two of his students, Messrs. A. D. White and Lewis Spalding. Owing to the large amount of territory to be covered, only a short time could be devoted to this region. The First Biennial Report, published in 1861, contained the results of this field work* (pp. 58-68). The light colored, argillaceous limestones of the Davis quarry, west of Ida, were identified as those of the Onondaga Salt Group, on account of the gypsum present. The same beds were believed to appear at Ottawa Lake and to be struck in the deeper portions of the Plum Creek quarries, and the suggestion is made that gypsum be sought for at these localities, as well as in the gorges of Otter Creek. The thickness of the Onondaga in Monroe county is given as 24 feet; the first 10 feet of which is a chocolate colored limestone, the remainder fine ash colored, argillaceous limestones, with acicular crystals (p. 140). The Upper Helderberg is given a thickness of 60 feet in the county, and was made to include the brecciated dolomites of Stony Point and Point aux Peaux, the two beds of oölite, the Sylvania sandstone and the purer limestones on the Macon.

The work of the survey was interrupted by the War of the Rebellion and not resumed again until 1869, with Dr. Winchell again State Geologist for two years. Materials for a valuable volume were prepared but were never published in the manner intended. Some of it, however, appeared in Walling's Atlas of Michigan and was subsequently put out (1873), as a small volume bearing the title "Michigan." The occurrence of the Lower Helderberg (Waterlime) had been announced in 1870. This formation was recognized in the quarries in the eastern part of the county and considered to attain a thickness of 60 feet. The geological map which accompanies the volume gives a narrow strip of Lower Helderberg, three to four miles wide, following the shore of Lake Erie, with a broad belt of Corniferous to the west and embracing nearly the entire county. Small islands of Salina, with marginal strips of Lower Helderberg, are represented at Ida and Ottawa Lake, and apparently also at Monroe and Brest. The Little Traverse appears as a narrow belt, with the general strike and position which the Corniferous ("Dundee") is now known to possess, while the Huron shale covers the remaining northwest corner of the county. This corner is just grazed by the Marshall sandstone. The formations which overlie the Lower Helderberg are thus seen to be displaced to the east. The following "generalized section" was intended to include all the Monroe county beds, excepting the Little Traverse and Huron, which are not here known in outcrop.

---

*1861. First biennial report of the progress of the G. S. of M. Embracing observations on the Geology, Zoology and Botany of the Lower Peninsula. Made to the Governor Dec. 31, 1860.

IV. Brown bituminous limestones, seen in most of the quarries of Monroe county; also in Presque Isle and Emmet counties, 75 feet.

III. Arenaceous limestone, sometimes resolving itself into beds of friable sandstone and incoherent sand. Monroe county; also Crawford's quarry, 4 feet.

II. Oölitic limestone, as in Bedford and Raisinville, Monroe county, 25 feet.

I. Brecciated limestone, sometimes concretionary, 50 feet.

§ 14. Rominger survey.

Dr. Carl Rominger began his examination of the rocks of our southern peninsula in 1873, making a detailed, careful study of all the beds and their fossil contents. The results of his three years' personal work are recorded in Vol. III, Geological Survey of Michigan, 1876. That portion of the report which deals with the rocks of Monroe, and the adjacent portions of Wayne county is recorded on pages 25 to 37. The limestones of this region he described under the single heading "Helderberg group," but recognizes an upper and lower division, equivalent to the Upper and Lower Helderberg respectively. The lithological characters of the beds are accurately noted and simple analyses given of the more important, some of which will be incorporated into this report. The Sylvania sandstone he gives a thickness of but 8 to 10 feet and, following the earlier reports of the Ohio Survey, regards it as probably the equivalent of the Oriskany sandstone, of New York (p. 29). The oölite of Plum Creek and Little Lake he regards as the geological equivalent of the sandstone (p. 28), being misled by the beds of mottled dolomite which underlie each, but which are actually many feet apart. A still more serious error was made in bringing the base of the Upper Helderberg down to the top of the Sylvania sandstone, based upon the lower percentage of magnesia in these beds. The quarries of Ottawa Lake, Little Sink, Lulu, Ida, Raisinville, Woolmith and Flat Rock are all in beds above the Sylvania and still contain practically enough magnesia for normal dolomite. Both lithologically and palæontologically these beds immediately above the Sylvania must be connected with those beneath.*

Dr. Rominger does not admit the occurrence of the Hamilton

---

*See Geological Survey Ohio, Vol. VII, p. 17.

(Traverse) in this portion of the State (p. 38), believing that from the thickness of 500 feet near Alpena, it thins out completely before reaching the southern boundary. Reasons will be given later for thinking that the Traverse is well represented beneath its heavy mantle of drift in the northwest corner of the county. Upon the geological map that accompanies Vol. III the structure of Monroe county is much simplified by uniting the Upper and Lower Helderberg into one division, not representing the Sylvania and imposing the St. Clair shale directly upon the Upper Helderberg.

§ 15. Work of present survey.

While searching for natural gas in the early fall of 1887 at the plant of the Eureka Iron and Steel Works, in Wyandotte, the drill from 730 to 1,235 feet passed through a series of layers of pure rock salt. The newspaper announcements of this incidental discovery caught the eye of interested parties in the East and experts were soon upon the ground. The remarkably pure beds of limestone, two miles distant, combined with unusual shipping facilities, made the region almost an ideal one for the manufacture of soda ash and caustic soda. Establishment after establishment has sprung up along the Detroit River, representing millions of outside capital and employing an army of workmen. Other extensive plants are seeking locations and are inquiring for high grade limestone. The rapid development of the Portland cement and beet sugar industries in our State has greatly increased the demand for natural products.

The records of the Wyandotte well above mentioned and of a well at Monroe down into the Trenton which were collected during the administrations of State Geologists C. E. Wright and M. E. Wadsworth were printed in Part II. of Vol. V of the State Reports. There is also a geological map of the lower peninsula in this volume, which shows the course of the Sylvania sandstone, and the terms applied to the various members of the rock series which we use. During this time the records of the Dundee and other wells were acquired by the State Survey, and by the spring of 1896 it was decided to arrange for a thorough survey of this most promising corner of the State and to render available at once, by means of a bulletin, what could be learned of its resources. The work was begun under Dr. Lucius L. Hubbard and after his resignation, continued and completed under the present organization. July and August, 1896, and August, 1897, were devoted to the field work by the writer, assisted the first season by Mr. W. D. Cramer and later by Messrs. R. R. Putnam and De Forest Ross. For purposes of comparison, a careful study was first made of the extensive Sibley quarry, north of Trenton, and of the smaller quarries and outcrops about the Detroit River. Within the county every known natural and artificial exposure of the rocks was visited, the strata studied, samples and fossils collected and each quarry platted. From convenient centers, a study was made of the soils and their distribution and much detailed information gathered in regard to the depth and character of the rocks, the nature of the drift deposits, water supply, timber and crops, indications of oil, gas, etc. From Ottawa Lake a side excursion was made into Ohio to examine the exposures of the Sylvania sandstone and adjacent strata. The delay in the publication of the bulletin necessitated a final general survey of the county, in order to bring the information to date and nearly two weeks in September, 1899, were devoted to this purpose. The Raisin was found to be exceptionally low and a favorable opportunity was afforded for studying the strata over which it flows. As to the results secured and conclusions reached the body of the report must be allowed to speak.

§ 16. Acknowledgments.

It is a pleasure to acknowledge here the uniformly courteous treatment received from the farming population of the county. Much of this report has been rendered possible only through information received from them. Only in a few cases, where they feared that they were being victimized by some new scheme, was information withheld or grudgingly given. It is hoped by getting the benefit of generalizations, based on their combined knowledge, that they may be, in part, at least, repaid. The numerous well drillers, with but a single exception, have given their valuable information, the result of years of labor and the expenditure of much money, freely and gladly. Especial acknowledgment is due Mr. John Strong, of South Rockwood, and his driller Mr. H. S. Dalton, for information and series of samples of the Newport well. To Church & Co., through their courteous manager Mr. K. J. Sundstrom, the survey is very especially indebted for maps, charts, negatives, analyses, and valuable information pertaining to the region, with every facility for the study of their extensive Sibley quarry. The same generous treatment was accorded by Mr. G. F. Smith, at the time president of the Michigan Stone & Supply Co., and by the officers of the Monroe Stone Co. We are indebted for our topographic base very largely to the county atlas published by Geo. A. Ogle and Co., of Chicago in 1896. Finally, to Mr. Ezra Lockwood and family, of Summerfield township, grateful acknowledgment is made for generous hospitality, conveyances and valuable information, the result of many years' intelligent observation and experimentation in the prairie region.

CHAPTER II.

DEVONIAN AND QUATERNARY FORMATIONS.

A. *Quaternary Deposits.*

§ 1. Thickness.

Except over areas covering but a few square yards, the rock beds of the county are concealed by a mantle of more or less unconsolidated material, varying in thickness from a few inches to about 150 feet. The average depth would probably be from 40 to 50 feet, although there are many square miles within which the depth to the rock is less than 25 feet. The deepest beds of this covering are found in the northwestern corner of the county, where just southwest of Milan, they reach a thickness of 150 feet. In the southeastern part of Erie township a thickness of 80 to 90 feet is attained. Extending in a northeast and southwest direction there are three belts along which this superficial covering is very much less, in some instances being practically absent and thus exposing the bed-rock. The most easterly belt of the three begins in the southern part of Whiteford township, extends northeastward across Bedford, northwestern Erie, the western part of La Salle, through the city of Monroe to Brest and into the eastern part of Berlin township. Throughout this entire extent the deposit rarely exceeds ten feet in thickness and is on an average much less, hence it is accompanied by numerous quarries and natural rock exposures. The middle belt is approximately parallel to the eastern just located and extends from Ottawa Lake sink, through the northeastern corner of Whiteford, across Ida, western Raisinville into the southern part of Exeter township, beyond which the deposit increases to 30 to 40 feet. Upon the map (Plate XV), there is shown by means of the contour lines, the depth of the rock from the general surface of the land. These contours thus show, also, the thickness of these deposits referred to. Just where the sand accumulations of the Forest Beach are added to those of the clay, an apparent deepening of the rock occurs as shown by the contours on either side of Lambertville and in Sections 19, 20 and 21, of Ida township. The third belt is less well defined, shorter and more interrupted, the thinner portions of the drift being located at Petersburg, Dundee and on the Macon, where it is but two feet thick.

§ 2. General nature.

The great bulk of the deposit above referred to constitutes the so called "drift," an accumulation for which the great continental ice sheet, to be later described, was responsible. This consists, in the main, of a great mass of stiff, blue clay, entirely without stratification and carrying varying proportions of sand, pebbles and boulders. This is technically known as "till." When thoroughly compacted and filled with stones it is popularly called "hard-pan," in which form it greatly retards the operations of ditching and well digging. Upon exposure to the atmosphere, as at the surface or by means of a natural or artificial excavation, the color changes from blue to yellow or a rusty brown, owing to the oxidation of the iron. The alteration in color may extend but a few inches, or it may reach to a depth of fourteen feet or more, as about Dundee. The change in color marks the lower limit of percolating surface water, which depends upon the structure of the bed itself. Embedded in the clay there are frequently encountered lenticular masses of "quick sand," more or less stratified and of varying thickness and extent. Less frequently beds of gravel, from fine to coarse, are encountered, but are probably not continuous under any considerable area. Some of the deposits reported as "gravel" by farmers and drillers are beds of sand simply, or till rather more heavily charged with pebbles than is usual. This is probably true of the beds of "cobble stones" reported as occurring at a depth of 25 feet in Sec. 20 (S. W. $\frac{1}{4}$, S. W. $\frac{1}{4}$) of Ash. At the bottom of wells in Sections 4 and 6, and in Sec. 20, at a depth of 30 feet, Milan township, a bed of gravel is reported. In Section 9, still nearer the surface, a three foot bed is said to occur, overlain by 13 feet of clay and underlain by hardpan. Southward in Dundee township, Section 8 (T. 6 S., R. 6 E.), gravel was encountered at 28 feet, and in Section 26 was found overlying the rock. Eastward in London township, Sec. 20, a fifty foot well stopped in gravel. In Summerfield township similar reports of gravel strata were obtained from both farmers and drillers. It overlies the rock in Sec. 4, with a heavy bed of blue clay above, but is struck in Sec. 7 at a depth of 14 to 16 feet and furnishes water at the place of T. M. Taft. In the same section (N. W. ¼, S. W. ¼), at John Long's place, coarse gravel was reached at a depth of 53 feet, overlain by a three foot bed of "putty clay." The gravel was penetrated three feet and the well abandoned because the hole could not be kept clean. In Sec. 27 there is on an average 1½ feet of a sandy loam, one to six inches of blue clay and beneath a stratum of rounded pebbles varying from the size of a pea to that of the fist. The layer is four to six inches in thickness, but may be represented by a few stones simply. Beneath this is a heavy deposit of yellow, followed by blue, clay and hard-pan. In Bedford township, Sec. 4 (N. E. ¼, N. W. ¼), a 3 to 4 foot bed of gravel is stated to overlie the rock, which is struck at 26 feet. With the exception of the last record all the reputed layers of gravel occur within the limits of Summerfield, Dundee, Milan and London townships. Some of them may be merely inclined gravel filled fissures or cracks.

§ 3. Boulders.

Scattered rather sparingly over the clay areas of the county are rounded masses of crystalline rocks, such as are known in place—nearest in Canadian regions to the northeast. In the western and northwestern portions of the county they repose directly upon the surface, but eastward are more and more embedded in the soil and frequently struck only with the plow. They consist in the main of gneisses, schists, diorite and diabase, and, occasionally, limestone, sandstone, and conglomerate. A well known type of the latter is represented by a boulder 6x3x2½ feet lying along the roadside at the S. W. ¼, N. W. ¼, Sec. 3 Milan. It contains rounded pebbles of brown and bright red jasper, very characteristic and readily recognized. The parent bed is in western Ontario, north of Lake Huron, and its fragments are found in Ohio, Indiana, Illinois, Wisconsin and even so far south as Kentucky and west as Iowa. In size these boulders vary from cobble stones, and less, up to masses weighing many tons. One of the largest in the county, and probably the largest in this section of the state, lies about one and one-half miles east of the village of Ida, upon the farm of Christopher Knapp, claim 521. It is an enormous mass of hornblendic gneiss, contorted, of a light gray color, having a length of 20 feet, maximum breadth of 15 to 16 feet and standing four feet above ground (See Fig. 1). Presumably there

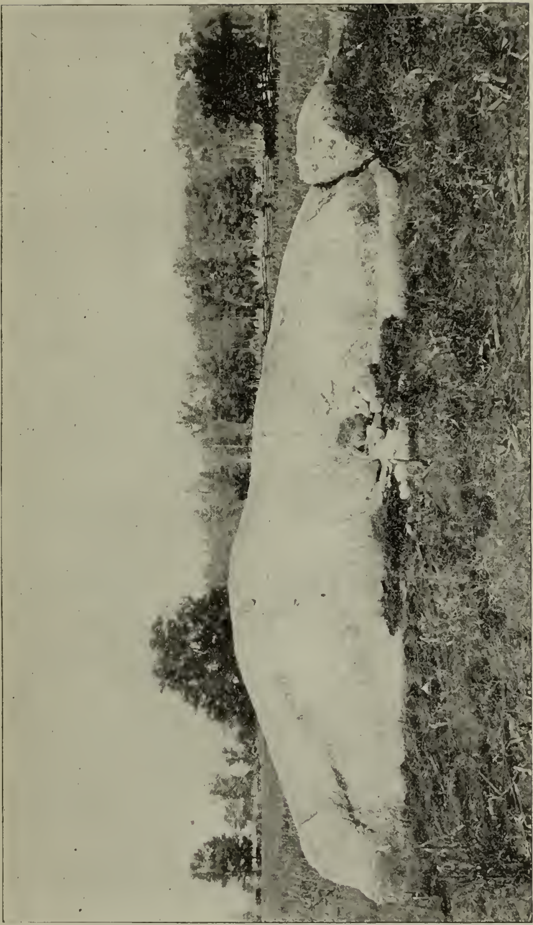


Fig. 1. Mammoth boulder transported by the great ice sheet and dropped east of the site of Ida. Four feet above ground: twenty feet long.

is as much or more below the surface as there is above, and it can scarcely weigh less than two hundred tons. A large fragment of what appears to be identically the same rock lies upon the S. E. ¼ of Sec. 27, Whiteford township, farm of F. B. Doty. The boulder is 6x10x3½ feet and there is said to be as much rock beneath the surface as in sight. Smaller fragments of the same rock are seen farther south.

A mass of limestone, large enough to be mistaken for an outcrop, lies in the western part of Frenchtown township, upon the property of Alexander Stewart (claim 21, N. River Raisin). It formerly projected above ground but building stone has been removed from it and there is now an opening into it 10 by 18 feet, containing three to four feet of water. It is of a light gray color, has a strong bituminous odor, is rich in corals and brachiopods and effervesces vigorously in dilute acid. It lies directly over a bed of sandy dolomite, very different in its nature from this material. Mr. Frank G. Strong, of Monroe, at one time did some boring about the mass and informs me that upon one side only was rock struck with the auger. It seems very probable that we have here an unusually large mass of Corniferous limestone, which was pushed, or carried, beneath the ice sheet from a point a few miles to the northeast and finally left embedded in the clay. In 1865 Winchell described numerous masses of exactly this nature, occurring in the northern part of Lenawee and Hillsdale counties, the southern and eastern portions of Jackson and southern and western Washtenaw.* These masses were occasionally so large that they were mistaken for outcrops, lime-kilns were erected and lime burned until the supply of stone was exhausted. From an examination of their fossil contents Winchell identified them as Corniferous and concluded that their state of preservation was such that they could not have been transported from the outcrops of this formation known to occur about Mackinac. All the masses of this nature then known lay to the north of the Corniferous outcrop in southern Michigan and northern Ohio and Indiana. The conclusion was reached that they had been frozen into the shore ice of a lake or sea, detached and floated northward, where they were gently dropped upon the melting of the ice floe. The evidence of a northward transportation of drift was further strengthened by the finding of delicate Hamilton and Marshall fossils as much as thirty miles north of the southern outcrops of these beds. In the case of the Stewart boulder described, we have an apparently identical mass of limestone lying to the south of the outcrop supposed to have furnished the others. The position of the Corniferous, Hamilton and Marshall beds in eastern Michigan and western Ontario is such that a movement of the ice sheet S. 60° W. would account for the location of the most northern masses described as occurring in this portion of the state, with a maximum journey less than one-half that required to bring them from the northern outcrops. At Stony Point Winchell found glacial striations bearing S. 60° W. This same set occurs at Point aux Peaux, and strikes S. 65° W. at Brest, according to the earlier observations of Hubbard. The glacial striæ, however, found at Trenton and several localities in Monroe county show conclusively that the ice sheet itself actually moved northwestward upon the northern side of the Erie lobe (Chapter VI, § 7), so that the journey made by the rock masses may have been a still shorter one. Much more extensive masses of the same character occur in northern Illinois near Freeport and were described in 1897 by Hershey in a paper upon "The Eskers of the Kansan Epoch."* These are referred to later by Leverett in his recent monograph on the Illinois Glacial Lobe under the heading "Transported rock ledges."† Some of these masses have not been so gently handled and consist in part of angular fragments of the limestone. Two of the largest taken together are stated to cover 100 acres and to attain a maximum thickness of 40 feet. According to Hershey they were pushed along in front of the ice and were never overridden by it.

---

*Some Indications of a Northward Transportation of Drift Materials in the Lower Peninsula of Michigan. Am. Jour. of Sci., Second Series, Vol. XL, pp. 331 to 338.

Only in Berlin and eastern Frenchtown is there any bunching of this surface material sufficient to suggest a morainic deposit. From Stony Point northward the boulders are more abundant, especially upon the "ridge," where the covering of clay is light. In several places the ground is greatly encumbered with cobble-stones, especially upon claims 528, 529, 530 and 531 (N. Stony Creek). In Berlin township, S. W. ¼, Sec. 33, the same cobbles occur in great abundance. It will be shown in another connection that these deposits mark the southern prolongation of a well defined, water-laid moraine, extending from the Huron River northward past Trenton, towards Detroit. (Chapter VI, § 8.)

---

*American Geologist, Vol. XIX, pp. 197-209, 237-253.

†The Illinois Glacial Lobe. Monograph XXXVIII, U. S. Geol. Surv., 1899, pp. 82-84.

§ 4. Post-glacial deposits.

Under the head of Quaternary belong not only the drift deposits described but others of an entirely different nature and history, which will be only briefly referred to here. Spread over nearly the entire till area of the county, is a layer of dark clay loam; very thin or absent in the western part, but increasing in thickness toward the east and southeast. Its absence over certain areas may be due to erosive agencies. It is quite free from pebbles, shows no distinct stratification, owes its dark color to organic matter and is, agriculturally, of very great importance to the county. No sharp line of demarcation exists between this superficial deposit and the underlying till, one seeming to grade into the other.

Passing northward from Sylvania, Ohio, to Oakville is a broad, irregular belt of surface sand, varying in breadth from two to eight miles. In many places the sand has been heaped up by wind action into mounds and ridges, the latter of which sometimes squirm across several adjoining sections. Near Temperance there branches off from this main belt a secondary one, extending northeastward to Carleton and beyond (See map, Plate VII). This is narrower and much more irregular, but otherwise similar. Transverse belts of similar sand almost completely connect these two belts in Raisinville and Exeter townships. From Milan village there extends southwestward across the township, through Dundee to the northwestern corner of Summerfield, a fairly continuous, but narrow strip of yellow sand, with occasional pebbly patches upon either side.

In addition to the clay and sand deposits of such wide extent, there are others, of a more local nature, to which attention may here be called. Along the rivers and smaller streams terraces of silt have been formed, of considerable breadth and thickness and consisting of clay, sand and organic matter. The surfaces of these terraces constitute the flood plains, in general, and receive slight additions with each inundation. Locally, where there have been lakes and marshes, or where these still exist, beds of marl, peat and bog-ore are found, or are now in process of formation. About some of the extensive springs, the waters of which are highly charged with lime carbonate, deposits of calcareous matter over leaves, twigs and moss, result in the formation of a "tufa."

B. Devonian Formations.—St. Clair (Genesee) Shales.

§ 5. General arrangement of Devonian formations.

If all the deposits which have just been described were removed and a general view could be had of the so called "bed rock," it would appear, approximately, as is shown upon the map (Plate I). This constitutes what is called a geological map, in which the belts of color represent certain groups of strata, which have a common structure, composition and history. Being formed within the limits of the same geological period certain distinctive names are assigned to these groups, or to their subdivisions. In Monroe County these strata all have a general northwesterly "dip," with their outcropping edges extending ("striking"), in a northeast and southwest direction. Obviously the strata which were latest formed are in the northwestern corner of the county and the next oldest, in succession, would be encountered as one passed southeastward, across the line of strike. This order of position will determine the order of description of the rock formations.

§ 6. Name.

The youngest member of this Monroe County series is the group of "St. Clair shales,"* so named from their occurrence along St. Clair River. They constitute the lower portion of Winchell's "Huron Group," described in his report of 1861 (pp. 71-80). In the early Ohio reports the beds are referred to as the "Huron shale," "Black shale," "Black slate," and "Shale stratum." Newberry in his report of 1873† describes two beds of shale, the Erie and Cleveland, which immediately overlie the Huron. These three were united by Orton into a single stratum which he termed the "Ohio Shale."‡ An upper and a lower division were recognized, for the latter of which he retained the name Huron shale, and it is this which forms the northwestern corner of Monroe County (See Map I). It is probably nearly equivalent to the Genesee shale of the New York series.

§ 7. General data.

Only about seven sections of the northwestern corner of Milan township are underlain by these shales, the main portion of the stratum lying in Lenawee and Washtenaw counties, and dipping at a low angle to the northwest. They are covered by 100 to 150 feet

---

*Geol. Sur. of Mich., Vol. V, 1895, pt. II, p. 21.
†Geol. Sur. of Ohio, Vol. I, pp. 152-167, 189-191.
‡Geol. Sur. of Ohio, Vol. VII, 1893, pp. 21-26.

of drift and so are struck only in the relatively deep wells of this region. The actual elevation of the base of the stratum is about 560 feet above tide at Milan (18 feet below the level of Lake Erie), while the elevation rises to 610 feet where it leaves the county. The highest elevation noted is in the extreme northwestern corner of Section 6, where it is about 625 feet above tide. Winchell gives an outcrop of shale of his Huron group as occurring near Adrian, Lenawee County.* If such an outcrop occurs the shales cannot be the St. Clair since these were struck in the well of the Adrian Gas Company at a depth of 524 feet from the surface. Good exposures, however, are found northward about the shores of Lake Huron and along some of the small ravines leading back from the lake.

§ 8. Thickness.

In the Adrian well above referred to, the shales regarded by Lane as the St. Clair show a thickness of 221 feet.† At Ann Arbor in the court-yard well, they appear to have a thickness of 275 feet, according to the same authority.‡ In Ohio these shales show a development of about 300 feet and in western Ontario at Corunna, Lambton county, 213 feet. At Sarnia, according to Brumell, they are reduced to 80 feet. The base of the bed at Ann Arbor has an elevation of 134 feet above tide; at Milan 560 feet, giving a drop in the fourteen miles, in this direction, of 426 feet, or about 30.5 feet to the mile.

§ 9. Lithological character.

Where well exposed, as upon Sulphur Island, Thunder Bay, these shales are seen to be black, very fissile, hard, crisp and sharp; approaching slate, when unweathered. They possess a certain amount of elasticity, and snap and crackle under the feet, as one walks along the beach. They are finely laminated and very evenly bedded. When exposed to the weather they assume a gray, or rusty brown color, from the oxidation of the contained iron. Efflorescences of sulphates of iron, or alumina, form over the surface where it is somewhat protected from the rain. The color becomes darker towards the bottom of the series, due to the greater amount of carbonaceous matter derived from vegetation. Such shales have an oily appearance and a strong bituminous odor. Beach fires on Sulphur Island are said to have burned as long as 16 months, although, ordinarily, the shales are incapable of sustaining combustion. The spontaneous distilla-

---

*First Biennial Report, 1861, p. 76.
†Geol. Sur. of Mich. Vol. V. Part II. Plate 1.
‡Page 47.

tion of this organic matter has yielded large quantities of petroleum and natural gas, products almost always associated with the stratum, in New York, Ohio, Ontario and Michigan. Crystals of pyrite and nodules of marcasite are of common occurrence in the shales. The latter is especially subject to chemical decomposition, forming compounds of iron and sulphur, which stain the shale and impregnate the percolating water. Spherical to ellipsoidal concretions, varying in size from an inch to six feet in diameter, are found embedded in the mass of shale. These consist according to Rominger, of lime carbonate 89%, magnesium carbonate 2%, with 7.5% of insoluble, bituminous and silicious residue. Crystals of calcite and siderite, sometimes with fragments of organic remains, are found toward the center of each concretion. The shales themselves have yielded but few fossils, either in Michigan or Ohio, and those found are mostly of plants. Rominger reports subordinate seams of lime rock showing "cone-in-cone" structure.

A recent number of the Journal of Geology* contains figures and descriptions of the concretions by Reginald A. Daly. The composition is shown to be approximately the same as that given by Rominger. This author calls attention to the deformation of the shale on all sides of the concretion and concludes that they were formed in place within the shale, that they antedate the period of joint development and final consolidation of the shale, and that the deformation resulted from the energy of the process of crystallization, due to a change in volume when the original bicarbonate of calcium was converted into the monocarbonate.

§ 10. Geological position.

Reposing as these lower beds do upon layers of undoubted Hamilton, and with the characteristics above presented, it is exceedingly probable that they are to be correlated with the Genesee shale of central New York. The description of lithological characters would apply as well to the shales about Canandaigua Lake as to those of Thunder Bay. That they cannot be regarded as Marcellus, as has been maintained by some, is proven by their position above the Hamilton beds. As yet, however, the lower portion of the St. Clair has furnished no fossils with which to strengthen this lithological evidence of equivalency with the Genesee. For the last forty years the views of those who have worked in this lake region are not in reality widely divergent. In his report of 1861 (p. 79) Winchell, relying upon the evidence of Billings and Hall says: "In this state of the case we shall be constrained for the present to regard the Huron Group of Michigan, extending from the conglomerate above the gritstones of Huron county, to the top of the argillaceous limestones of Partridge Point, as probably representing the rocks of the Portage Group of New York." In a paper read before the Geological Society of America, in December, 1893, Brumell, of the Canadian Geological Survey, still refers this shale series to the Portage, but in his table includes the Chemung.[*] According to the later publications of the Ohio Geological Survey, Newberry did not sharply separate his Huron shale, from his Erie and Cleveland above it and in 1873[†] he reports the occurrence of diagnostic Portage fossils in the Huron, or lowest member of our St. Clair shale. In his chart of geological time, however, he drops the Huron shale to the level of the Genesee. In the Erie he found positive palæontological proof of its equivalency with the Chemung (p. 164). Three years later Rominger referred the entire series to the Genesee.[‡] In a little table of the divisions of the Devonian system published in 1886 (Geological Studies, p. 389), Winchell makes the Erie shale of Ohio the equivalent of the Portage and Chemung. The Huron shale he correlates with the Genesee and all together comprise his Huron group. This view harmonizes the apparently discordant views of the various workers and was accepted by Orton. In his report of 1893, he says.[§]

---

*February—March, Vol. VIII, No. 2, pp. 135-150. "The Calcareous Concretions of Kettle Point, Lambton County, Ontario."

"The Ohio shale, as Newberry first proved, is certainly the equivalent in the general scale of the Genesee slate, the Portage group. and the Chemung group, the last named being itself a formation of great thickness and extent in New York and Pennsylvania. In other words, the shales of our column fill the entire interval between the Hamilton proper and the Catskill group, and in the judgment of some geologists a wider interval than that named above."

In a paper upon the Devonian system in Canada, published in October, 1899, Whiteaves accepts the Genesee equivalency of the black shale found at Kettle Point, Lake Huron.[¶] In the light of our present knowledge then, the 70-80 feet of the shale, found in the northwestern corner of Monroe County, belongs largely, if not entirely, with the Genesee shale of New York.

---

[*] Bull. Geol. Soc. Vol. IV, 1893, p. 227.
[†] Geol. Sur. of Ohio, Vol. I, p. 154.
[‡] Geol, Sur. Mich., Vol II, 1876, p. 74.
[§] Geol. Sur. Ohio, Vol. VII, pp. 23-24.
[¶] Amer. Geologist, Vol. XXIV, p. 231.

§ 11. Lithological history.

The materials of which these shales are composed were accumulated in the off-shore region of the ocean, or some great inland sea. The fineness of the particles indicates that this region was somewhat remote from the land, yet near enough to receive from it, through the agency of waves and currents, the materials resulting from the erosive agencies continually at work. Deposits of such thickness could probably only have been formed over a slowly subsiding sea bottom. Conditions were not favorable for the ordinary forms of marine animals, such as the corals, mollusca, echinoderms and crustacea, and hence the beds are relatively free from the lime carbonate which these forms secrete from the water. The presence of so much bituminous matter indicates that marine vegetation, of a certain type, was very abundant. This bituminous constitutent of the shale is due very largely to the presence of enormous numbers of minute disc-like bodies, with thick carbonaceous walls. These were discovered by Dawson in the shales of Kettle Point, Lake Huron and described by him in 1871, under the name *Sporangites Huronensis.** According to Orton, however, they had been seen previously by B. W. Thomas in the water and clays of Lake Michigan. They are about .01 of an inch in diameter and under the microscope show a papillose exterior, with an attachment scar on one side and a more or less elongated gaping slit upon the other. Remains of *Calamites* and *Lepidodendron* were found in association and Dawson regarded them as spore-cases of the latter tree. Without having seen this article by Dawson, in 1882, Orton described these bodies in the above mentioned journal,† as spore-cases, containing both macrospores and miscrospores. In August, 1883, Dawson read a paper before the American Association for the Advancement of Science, entitled "On Rhizocarps in the Palæozoic Period."‡ From material furnished by Derby from Brazil two new species were described, *S. Braziliensis* and *S. bilobatus.* The spore-cases showed the macrospores in position, so much resembling those of the floating fern of the European rivers, *Salvinia natans*, that the generic name *Protosalvinia* was suggested. His former *Sporangites Huronensis* he considered as the macrospores of related plants, but with their envelopes lost. A similar interpretation is put upon the forms by Clarke who found them abundant in the Marcellus shale of Ontario county, New York. They are associated with immense numbers of minute sub-spherical bodies, regarded as the microspores.* These later discoveries are in entire harmony with the view early advanced by Newberry in his Ohio report for 1873, page 156. He there calls attention to the difficulty in conceiving of such widespread shallow water conditions, capable of furnishing the necessary shore vegetation, with the evidence of the proximity of the shore so completely wanting. He referred the bituminous matter to former floating plants and imagined the entire area of the black shales to have been one great "Sargasso sea." Fragments of rushes and trees were occasionally drifted seaward by the same current which distributed the sediments themselves. About such fragments, or the bones and teeth of the terrible fish which inhabited these waters, concretions formed, while the mud was still soft. Later great beds of sediment were superposed, the weight of which compressed the soft material to probably but one-half its original volume, forced out the excess of water and produced the crisp, fissile shale.† The pyrite and marcasite were formed wherever soluble sulphates came in contact with putrefying organic matter and oxide of iron, as shown by Bischof many years ago and later by Forchhammer. The sulphates may be derived from the organic matter itself or be in solution in the sea-water in which it is immersed. When sea weeds and iron oxide are in contact double decomposition ensues and the above sulphides of iron result. Forchhammer mentions a beautiful illustration of this action on the western shore of the island of Bornholm where *Fucus vesiculosus* is very abundant, and all the pebbles on the bottom are coated with a yellow coating of pyrite. Upon exposure, however, it is converted into a sulphate of iron. The author concludes with the following clear statement, "Thus it follows, that wherever putrifying sea-weeds come in contact with ferruginous clay, iron pyrites must be formed, which penetrates the clay, and on weathering first forms sulphate of iron, and if no lime be present, will ultimately, by a new decomposition, change into sulphate of alumina."‡

---

*American Journal of Science, 3d Series, Vol. I, pp. 256-263.

†A Source of the bituminous matter in the Devonian and Sub-Carboniferous Black Shales of Ohio, Am. J. S., 3d Series, Vol. XXIV, pp. 171-174.

‡ Proceedings, 1883, pp. 260-264.

---

*On Devonian Spores. American Journal of Science, 3d Series, Vol. XXIX, 1885, pp. 284-289.

†It should be said, however, that the presence of rock salt in the St. Clair formation, beneath Bay City, indicates other conditions than those of an open sea.

‡British Association for the Advancement of Science, 1844, pp. 155-169.

C. Traverse (Hamilton) Group.

§ 12. Name and geological position.

To the beds of soft shale and limestone, which lie conformably beneath the St. Clair, the term Hamilton was applied by Winchell in his First Biennial Report. Later, to the same series, the name Little Traverse was applied by the same author. In 1895, Lane suggested the name Traverse alone, since the beds occur in the Grand Traverse as well as the Little Traverse region of Lake Michigan. Rominger used the name Hamilton in describing these Michigan beds and for their equivalents in Ohio the same was used by Newberry. For one member of the group, apparently the only representative in Ohio, Orton retains the name Olentangy shale, a name first suggested by N. H. Winchell for a bed of shale exposed in Delaware County. Hamilton has been very generally, if not uniformly, employed for this series by the Canadian geologists who have worked in the adjoining territory of Ontario. Whatever the name, all workers are agreed from the geological position of the beds, their lithological characters, and their numerous and beautifully preserved fossils, that they are the western representatives of the Hamilton of New York, lying between the Marcellus and Genesee shales.*

§ 13. General data.

An inspection of Plate I, shows that this group covers the northwestern corner of Dundee, nearly the whole of Milan and the northwest half of London townships. It enters from Lenawee County, extends northeastward as a belt from five to six miles wide and continues into Washtenaw and Wayne counties. Its apparent breadth is increased by the topography of its upper surface, for it and the St. Clair shales have been considerably eroded, as shown upon Plate VI. In the lower section, taken along the line of the Toledo and Ann Arbor railroad, at the left hand the Hamilton beds are designated as limestone and shale. They are seen to have been cut to a level below that of Lake Erie, which results in considerably increasing the breadth of the outcrop beneath the drift. The thickness of this overlying drift increases quite regularly, in consequence, from about 45 feet at the southeastern corner of Milan township, to about 150 feet, just southwest of the village. The actual elevation, above

---

*I used the name Traverse to include Hamilton *and* Marcellus, and so did Winchell, in which usage it would be practically equivalent to Erian in the sense suggested by Clarke and Schuchert, L.

tide, of the surface varies from 636 feet in the northwestern part of Dundee township to 549 feet, where the drift is heaviest southwest of Milan. The dip of the beds is the same in direction and amount as that given for the St. Clair. There are no known exposures of these beds in this section of Michigan, or in any adjoining locality in either Ohio, or Ontario.

§ 14. Thickness.

From well records in northwestern Ohio and southeastern Michigan the Traverse group is known to be rather weakly developed, but to thicken to the north and east. The greatest development known in Ohio is but 20-30 feet according to Orton and in many regions it is not developed at all, the St. Clair then resting upon the underlying Dundee (Corniferous). In his map of the geology of the southern peninsula, published in 1876, Rominger does not represent the Hamilton at all in the southern portion of the state. In the deep well at Adrian there are 95 feet of limestone and shale which may properly be referred to the Traverse. At Ann Arbor, in the court-yard well, 70 feet of bluish limestone with some clay, were penetrated by the drill, probably without reaching the bottom of the series. This is regarded by Lane as Traverse, by Rominger as Upper Helderberg (Corniferous) and by Winchell as both, in part. At Royal Oak 215 feet of limestone and shale are referred to the Traverse. On the St. Clair river the total thickness is 300 feet. Eastward in Ontario, at Oil Springs, the group is 240 feet, at Petrolea 296 feet and at Kingstone's mills 396 feet in thickness. About Alpena it has increased to 600 feet, according to estimates of Rominger. Within the limits of Monroe County the bed has not been completely penetrated and we have no reliable data from which to determine its thickness. It is probably, however, not far from 100 feet, judging from the dip of the rocks and the apparent outcrop and surface topography of the beds. This estimate agrees also with the thickness found at Adrian.

§ 15. Lithological characters.

In the typical regions of west central New York the Hamilton beds consist of soft, bluish calcareous shales, with a few thin layers of bluish to gray limestones; the principal one of which is the so called "Encrinal limestone," scarcely more than a foot in thickness, but remarkably persistent. The shales break into coarse, lumpy fragments, not particularly fissile, never crisp and elastic as are the Genesee just above. When struck they seem dull and dead and when wet give a strong earthy odor and soapy feel. They readily soften into a blue clay when sufficiently exposed to the weather. These characters are always sufficient to readily distinguish the Hamilton shales from those of the Marcellus, Genesee and Portage. The Michigan representatives of these Hamilton beds seem to retain enough of these characters so that they may be separated from the St. Clair above and the Dundee beneath, even when their fossil contents cannot be procured. In southeastern Michigan and western Ontario there is a far greater development of limestone, at the expense of the shale, than in New York. Of the 95 feet in the Adrian well, according to the driller's log, 80 feet consisted of limestone, beneath which was 15 feet of black shale. In the Ann Arbor well referred to above, the 70 feet seems to have been largely limestone with the lower portions of the magnesian variety. Upon the St. Clair River the following section of the group occurs, as published by Lane in Vol. V, Michigan Geological Survey, Part II, (pp. 24-25).

Hard pyritiferous argillaceous limestone	2 feet.
Shale, "soapstone"	12 feet.
"Top limestone," often gaseous	80 feet.
Shale, "top soapstone"	150 feet.
"Middle limestone"	4 feet.
Shale, "lower soapstone"	65 feet.
"Bottom Limestone." (Corniferous.)	

A somewhat similar series of beds occurs about Petrolea, Ontario, of which the following represents the average section in thousands of wells:

Stiff blue boulder clay, drift	100 feet.
"Upper limestone," with little black shale at top	50 feet.
Bluish gray and drab shale, "soapstone" with few hard layers	120 feet.
"Middle limestone"	15 feet.
"Soapstone," with two or three hard beds	40 feet.
"Lower limestone" (Corniferous), giving oil at	45 and 135 feet.

The Traverse shales in Michigan are of the character ascribed to the typical Hamilton beds of New York, soft and bluish with a rather high percentage of lime carbonate. Certain layers may become much darkened, however, by bituminous matter. The limestones are typically bluish and argillaceous, but they may become darkened also. Fossils are exceedingly abundant in certain beds and beautifully preserved. The most common are various groups of the mollusca, corals, bryozoa and crinoids.

In the comparatively few wells sunk through the drift over the Traverse belt in Monroe County the description of the rock is very unsatisfactory. It is generally spoken of as hard or soft, as we might expect from the sections above given. From Milan to the southwestern corner of Sec. 18, Milan township, several records of a very hard rock having been first encountered were obtained. In the village of Milan, according to one driller, the rock is an "exceedingly hard quartz rock," according to a second it is a "hard sandstone." Records of sandstone (probably dolomite) were obtained at the southwestern corner of Sec. 18 at Stephen Olds and J. C. Miller's. Two other records of a similar rock were obtained in the northwest and southwest quarters of Sec. 7, London township. At Charles Sanford's N. W. ¼, S. W. ¼, Sec. 9, Milan a very hard rock was struck at a depth of 112 feet. This was so hard that only a few inches could be drilled each day and it was entered but eleven feet. Another hard rock was reported at the N. E. ¼, N. W ¼ of this same section. At the place of Samuel McMullen, N. E. ¼, N. E. ¼, Sec. 17, a well was put down to a depth of 309 feet, rock being struck at 95 to 100 feet. The rock was said to be "shell limerock, more or less honey-combed," and yielded no water. Limestone was also struck at the S. W. ¼, N. E. ¼ Sec. 22, at Patrick Nolan's, in his well 171 feet deep. Rock was struck at a depth of 112 feet, and at 150 feet what seemed to be sandstone. A strong flow of gas was obtained at a depth of 145 feet, was lighted and burned all one night. Mr. B. R. Ford reports limestone at the S. W. ¼, S. E. ¼, Sec. 14, in his 110 foot well. "Soft white rock," which might refer to a much softened limestone, or to a highly calcareous marly shale, was struck at a depth of 96 feet at the place of E. E. Spink, Sec. 26, N. W. ¼, N. W. ¼. Two records were obtained in this region which are much more suggestive of the typical Traverse shale. At a depth of 100 feet a "soapstone" was reached in the southeast quarter of Sec. 3, upon the place of Samuel Campbell. Thirty-five feet of this "blue soapy stuff" were entered. At Charles Campbell's N. W. ¼, S. W. ¼, Sec. 5, rock was reached at a depth of 142 to 143 feet. It is reported as a "soft mud rock, or soapstone." This was entered twenty feet when a "granite rock" was encountered. In the light of these facts it is difficult to predict the character of the bed which will be found beneath the drift at any given point within this Traverse area. The problem is complicated not only by the number of beds, of such varying character, but also by the topography of the rock surface.

§ 16. Lithological history.

During the time required for the accumulation and deposition of the marine sediments which form the Traverse beds, broad open sea conditions were changing to those which characterize the off shore. These changes took place in consequence of oscillations in the sea-bottom, causing the shore line to recede or advance; or in the amount and distribution of the fine detritus from the land, carried by waves and currents. When the mud deposition prevailed beds of clay were formed, which required only great pressure to become a shale. The presence of bituminous matter in sufficient quantity to color the deposit black or brown, indicates that the conditions had thus early been established which gave to the St. Clair shale its bituminous character. Conditions were favorable also for numerous forms of life which secrete lime carbonate from the sea-water and as their remains were covered by the deposits they were preserved entire, or after disintegration were mingled with the mud. During long periods the amount of mud was greatly diminished and in this clear open sea bryozoa, corals and crinoids flourished in abundance. Their remains accumulated, were cemented together with a calcareous slime and after being subjected to great pressure and some heat, were partially crystallized, forming the beds of limestone. If sandstone actually exists as is stated by the records given above, shore conditions must have prevailed temporarily and beds of sand accumulated, which were later cemented into compact rock, but probably there is no real sandstone.

D. Dundee Limestone.

§ 17. Name and geological position.

By this local name the present State Geological Survey designates the great limestone belt, which in Michigan, Ohio, and Ontario underlies the Traverse just described. It extends in all directions from southeastern Michigan and covers hundreds of thousands of square miles in the lake region, the Ohio and Mississippi valleys. It represents the upper member of a group of four, which are found well exposed in the Helderberg Mountains of eastern New York and to which group the name Upper Helderberg was given by the geologists of that state. Of this group the Caudagalli grit, Schoharie grit, and Onondaga limestone give out before reaching Michigan, while the Corniferous is the sole representative here. This was so named from the beds and nodules of hornstone which seem quite characteristic of it (*cornu*, a horn; *fero*, I bear), both in New York and Michigan. Newberry and the Canadian geologists generally have used the term Corniferous in referring to the limestone. A. Winchell and Orton have preferred Upper Helderberg, although the former in 1886,* includes the four New York members under the general term Corniferous Group, following Dana.†

Rominger in his report of 1876 uses Helderberg alone to include this Dundee and the underlying so called Monroe beds, but recognizes an upper and a lower division. By early geologists the Hamilton, Corniferous and Niagara limestone in the states to the south and west, were known collectively as the "Cliff limestone." In his state report for 1893,‡ Hall proposes "Onondaga" for the two beds originally designated Onondaga and Corniferous, the hornstone being found distributed throughout the series. In view of this use of terms to designate the same bed of limestone, it seems wise to retain, in a report of this character, the local name given by the present survey.*

---

*Geological Studies, p. 390.

†Two papers by N. H. Winchell before the American Association for the advancement of Science refer to the correlation of these limestones and may be summarized here. In 1873 (p. 100) a paper on the Devonian limestone in Ohio gives a section of five members, the bottom one, the Sylvania sandstone (?) being considered equivalent to the Oriskany. The two upper members are bluish and the author contrary to Newberry, would place them with the Hamilton, although they are colored Corniferous on the Ohio County maps. The third member is a light saccharoidal crinoidal limestone (our Dundee limestone?), and the fourth a vesicular or compact magnesian limestone (Monroe beds above the Sylvania?) often popularly mistaken for sandstone. In 1875 (part II p. 57) "On the Parallelism of Devonian Outcrops in Michigan and Ohio," he returns to the discussion of the border line between Hamilton and Corniferous, and shows how A. Winchell on paleontological grounds referred most of these Devonian limestones to the Hamilton, reducing the Corniferous to insignificant dimensions, while Newberry called them all Corniferous, and Worthen called the blue argillaceous limestones Hamilton (our Traverse), and the lower light colored assigned to the Corniferous. According to the author we have the following section from above:

1. Blue limestone.
2. Crystalline crinoidal limestone.
3. Arenaceous limestone.

The Water-lime of Ohio, beneath, has three different lithological aspects, to wit: thin bedded, fine grained drab, with distorted wavy bedding; harsh heavy bedded magnesian with wavy bituminous or carbonaceous films; in patches brecciated, this structure obliterating the true bedding and hardening the whole mass.

‡Thirteenth annual report of the State Geologist, Vol. I, 1894, 207.

§ 18. General data.

An inspection of the geological map of the county (Plate I), shows the Dundee beds striking northeast and southwest, forming a belt, varying in breadth from four to five miles? This enters, from Lenawee County, the northwestern part of Summerfield and the southwestern corner of Dundee townships, grazes Raisinville and forms the southeastern half of London and the northwestern half of Exeter townships, passing into Wayne County. Although conformable with the lower Traverse beds the general dip to the northwest is believed to be less than that given for the upper Traverse and lower St. Clair beds. It is probably from 20 to 25 feet to the mile upon an average, although locally it may be much more or much less. Mr. T. J. Brandt, foreman of the Christiancy quarry, on the Macon, for a number of years, estimates the dip in the 40 rods across as three feet, or twenty-four feet to the mile, and to be in the direction of W. N. W. In the Pulver quarry at Dundee it is much greater, being four and one-half feet in 200, or about 119 feet to the mile, and evidently local. The line of junction of the Dundee with the Monroe is believed to cut through Petersburg and very near Raisinville postoffice. At the latter place, however, the rock lies too deep to be reached by the river and there are no exposures in the bed for some distance upon either side, the river being through this region deep and sluggish. The highest surface elevation of the rock is at the county line, west of Petersburg, where it is 650 feet above tide level.

---

* A rearrangement of the New York series has been recently proposed by Clarke and Schuchert in *Science*, December 15, 1899. (See also Amer. Geol. February, 1900.) The following portion includes the rocks described in this report:

System.		Group.	Stage.	Michigan equivalent.
Devonic..	Neodevonic.	Chautauquan.	Chemung beds.	
		Senecan.	Portage beds. Genesee shale. Tully limestone.	St. Clair shale.
	Mesodevonic.	Erian.	Hamilton beds. Marcellus shale.	Traverse group.
		Ulsterian.	Onondaga limestone. Schoharie grit. Esopus grit.	Dundee limestone.
	Paleodevonic.	Oriskanian.	Oriskany beds.	(hiatus?)
		Helderbergian.	Kingston beds. Becraft limestone. New Scotland beds. Coeymans limestone.	
Ontaric or Siluric	Neontaric or Cayugan		Manlius limestone. Rondout waterlime. Salina beds.	Monroe beds (?)

A more or less gradual fall occurs northeastward to the Wayne county line where it is not far from 580 feet, or 70 feet lower. From the river at Raisinville the contours (Plate I) indicate that there is a broad shallow trough in the bed, sloping northeastward, to be more fully described in another connection. (Chapter VI, § 2.)

§ 19. Drift covering.

The superficial covering of drift and soil does not exceed 70 feet and would average perhaps 35-40 feet, so that the bed lies much nearer the surface than the other two described. There are no natural outcrops although the beds are exposed in the bed of the Macon, northeast of Dundee and in the Raisin also. At Dundee the solid layers are exposed in the river just below the dam, but above it are covered by 2½ to 3 feet of sediment. In the western and southwestern portions of Dundee township the maximum covering occurs. At Petersburg slabs of Dundee limestone have been removed from the bank and assumed to have been *in place*, although the limestone in the bed of the river belongs to the Monroe. The junction of the Traverse and the Dundee in the southeastern part of Milan township is covered by about 45 feet of drift. Northeastward the bed has about the same amount of covering, which in the northwestern part of Exeter is increased to from 50 to 60 feet. It is very unfortunate that such valuable layers are so deeply buried and exposed only in the beds of streams where the problem of getting rid of the water is a very serious one.

§ 20. Thickness.

No complete section of the beds has ever been obtained within the limits of the county and its thickness can only be approximated. Judging from the dip and breadth of its supposed outcrop, beneath the drift, it cannot be far from 100 feet. In Ohio the maximum thickness is given as 75 to 100 feet. In the Adrian well the Dundee could not be differentiated from the Monroe. At Wyandotte and Trenton only a portion of the bed was penetrated, while at Detroit it was not entered at all. At Petrolea, Ontario, it is about 200 feet thick and at Alpena 120 feet. Winchell gives the formation at Mackinac a thickness of 275 feet but he included beds that are now known to belong to the next lower division.

§ 21. Lithological characters.

The Dundee is essentially a pure limestone formation with minor streaks and beds of an impure form of quartz, known as chert, the *hornstone* above referred to. The limestone varies in color from a light gray to brown, in some cases running into blue. The purer varieties show numerous cleavage faces of calcite and are heavily charged with fossils and their fragments. The argillaceous ingredient, so abundant in most of the Traverse limestones, is present in but small quantity, usually a small fraction of one per cent, but may run up to six to seven per cent in certain beds. A very small amount of iron is present (see analyses in Chapter IV, § 2), and the silica in the limestone varies from only a trace up to 9 or 10 per cent. Carbonate of magnesia is present in variable quantities in the various beds, some being remarkably free from it, while in others it may run up to 25 per cent. Analyses of the drill cores at the Sibley quarry show that the amount gradually increases toward the base of the series. The limestones always give a vigorous bubbling, (effervescence), with cold dilute hydrochloric acid when it is applied to the solid rock. Most of the beds have a strong oily odor and semi-fluid bituminous matter frequently collects in the cavities of fossils. At Petrolea this limestone series yields oil at 45 and at 135 feet.

In the Monroe County and Trenton quarries the upper beds are thin-bedded and shattered, probably due to the action of the great icesheet and later atmospheric agencies. Deeper layers may become heavily bedded, reaching a thickness of several feet. The same layer may be heavily bedded in the deeper portions of the quarry, but at its outcrop beneath the drift appears thin-bedded and much disrupted. Seams of clay very frequently separate the layers, washed in from the surface very probably by percolating water. Orton recognized in Ohio an upper and a lower division of the series. The upper division is more often blue, contains less chert and the beds seldom reach one foot in thickness. The lower is lighter colored, gray, drab and brown, contains more chert and the individual beds may reach a thickness of five feet. The Dundee is not sufficiently exposed in southeastern Michigan to say whether, or not, these divisions can also be recognized here. However, the characteristics of the lower division are all seen in the Dundee, Macon and Sibley quarries, while the upper half of the series is nowhere exposed.

In Michigan the Dundee forms the base of the great Devonian system, sharply separated by its fossil contents from the uppermost

Silurian beds, to be described in the next chapter, but with no evidence of any great structural break. The crustal movements which disturbed the Silurian beds in other sections of the world did not extend to Michigan, although the higher forms of life evolved as the result of such wide spread changes, promptly moved in. The spines and teeth of fishes are not infrequently found at the Sibley quarry, but the underlying Monroe beds have nowhere furnished any trace of a vertebrate. Lithologically the rocks are easily separated when specimens can be obtained, the Monroe limestones being of the dolomitic (magnesian) type and responding very slightly to cold dilute acid on the solid rock. In the drillers' log, however, it is impossible to separate them, and hence the desirability of saving samples of the beds penetrated.

[It is quite possible that there is more of a break between Dundee and Monroe, than appears stratigraphically in this county. In the table of formation equivalents, several appear to be omitted between them. Moreover beside the sudden paleontological difference there are conglomerates near the dividing line at St. Ignace. L.]

§ 22. Lithological history.

The relatively small amount of argillaceous and silicious matter in the limestones would indicate that their materials were accumulated far enough from the shore to escape the ordinary sediments which so largely made up the Traverse and St. Clair beds. Open but shallow sea conditions prevailed throughout the entire period and in the warm pure waters bryozoa, corals, crinoids and mollusks flourished in most wonderful profusion. Veritable coral reefs were formed over wide areas, many of the great colonies still standing where they grew, but imbedded in a matrix of fragments and calcareous slime, the result of wave action. Sharks of a strange type were numerous and contributed their spines and teeth after death. The floating vegetation had not yet, to any extent, invaded the sea, and this form of bituminous matter is absent. The oil which impregnates the rock was derived from the animal remains and was probably formed while the rock itself was in process of formation. Later the great pressure of superincumbent beds, with some heat, and the action of the carbon dioxide of the water compacted and partially crystallized the mass.

According to an estimate made by Dana, limestones due to coral accumulation alone, may gain one-sixteenth of an inch yearly, or five feet in 1,000 years. This growth he thinks is more rapid than when the limestone results from accumulation of shell remains. To have formed the 100 feet of Dundee limestone would then have required 20,000 years, upon the supposition that it took place at the maximum rate and that there were no periods of halt. While the organisms above referred to were secreting from the water the lime carbonate which it held in solution, other groups, such as diatoms, polycystines and sponges, were appropriating its silica and working it over into their hard supporting and protective structures. Their remains were finally added to the calcareous deposit and contributed to its supply of silica. The two foot bed of chert at the Sibley quarry shows equal quantities of lime carbonate and silica, from 43 to 44 per cent each, with nearly two per cent of magnesium carbonate and two per cent of alumina. The few fossils which it contains are all in silicified condition. It is not easy to satisfactorily account for the existence of such a bed, since it must have been formed before the limestone, just above it and subsequently to that of the bed just beneath. We cannot assume that the silica of the limestone beds was taken into solution and afterwards deposited, as in the case of nodules and veins of flint in the chalk beds. According to Maschke 100 parts of water, by weight, containing carbon dioxide, are capable of dissolving .078 parts of this amorphous silica. Or, stated differently, one cubic foot of such water is capable of dissolving .78 ounces of amorphous silica. According to Hunter sea water contains for each 100 vols. from .63 to 1.69 vols. of carbon dioxide gas. According to the researches of Buchanan sea water upon boiling will give off 2.3 vols. per 100 vols. and upon evaporation to dryness Jacobson found that twice this amount would be liberated. This gas is believed to be in some loose chemical combination since it is greatly in excess of what would be held by the water in response to the ordinary law for gas absorption by a liquid. Dittmar believed that there is practically no free carbon dioxide in the ocean water. The alkaline condition of sea water would enable it to dissolve somewhat more amorphous silica than would be due to the carbon dioxide alone. However, Dittmar, found in his analyses of samples of sea water gathered during the year 1873-6, by H. M. S. Challenger that there was a trace only of silica. If we assume the waters of this ancient sea to not differ essentially from those of today, except to have been saturated with silica, it would require a depth of about 3,000 feet of water to hold in solution the silica in the two foot bed of the Sibley quarry. If we assume that the chert bed was deposited as the result of the evaporation and concentration of the waters of an inland sea, it would require that the level be lowered about 3,000 feet. There is reason to think that this sea was comparatively shallow and becoming more so as time advanced.

Dittmar found that sea water is capable of becoming intensely alkaline, locally, through the agency of a limited amount of free carbon dioxide. In his experiments sea-water with an alkalinity expressed as 50.2 milligrams per liter, when saturated with carbon dioxide gas and digested for some time with calcium carbonate, shows an alkalinity of 314.2 milligrams. When magnesium carbonate is used, instead of the calcium, the alkalinity is increased to 1234 milligrams per liter. After being dissolved the magnesium carbonate and the sodium chloride suffer double decomposition with the formation of a carbonate of soda and a double chloride of sodium and magnesium. It is to the carbonate of soda that the greatly increased alkalinity is due and only a limited amount of the carbon dioxide gas is required since it is again returned in the reaction.

This increased alkalinity would enable the water to hold larger quantities of amorphous silica and if such silica were at hand it would be dissolved. This water upon being diluted, or having its alkalinity neutralized in part, would be compelled to deposit its silica and owing to the attraction which exists between molecules of the same substance, would tend to mass itself about the fragments of silicious organisms. In this way there would be produced an amorphous matrix with embedded fragments of organisms originally silicious. The few calcareous remains present would readily become silicified in such saturated water and we may readily imagine that while these conditions prevailed the bryozoa, corals and crinoids would be killed in the region affected, only a few hardy brachipods remaining, and the formation of limestone be temporarily suspended. The large amount of lime carbonate present in such finely divided state could have been precipitated directly or washed in by waves and currents from adjoining areas over which normal conditions prevailed. This explanation seems to fit best all the phenomena met with in the Dundee chert beds.

CHAPTER III.

SILURIAN FORMATIONS.

A. Monroe Beds.

§ 1. Name and geological position.

For this extensive series of beds, to which so many different names have been applied, it is convenient to have a definite local name. In his report published in 1861, A. Winchell describes the greater part of the series as the "Onondaga Salt Group" (pp. 57-60), but some of the lower beds exposed in the county, those at Stony Point and Point aux Peaux, he includes in the Devonian. In 1870 he recognized the latter beds as equivalent to the Waterlime division of the Lower Helderberg, of New York, *Leperditia alta* and *Spirifera modesta,* were found in the county, and on Put-in-Bay island *Eurypterus remipes.* Three years later a map was published showing the geology of the lower peninsula* upon which there is shown a narrow strip of Lower Helderberg, from three to four miles wide following the shore of Lake Erie. Narrow belts of the same are represented as surrounding the small patches of Onondaga, or Salina, at Ida and Ottawa Lake quarries. Newberry in 1873 describes these same beds as the Waterlime Group of the Helderberg formation of New York. He had accepted for the Upper Helderberg the name "Corniferous Group" and restricted Helderberg to what had been known eastward as the Lower Helderberg, made up typically of five divisions; the Waterlime, Lower Pentamerus limestone, Delthyris shaly limestone, Encrinal limestone and the Upper Pentamerus limestone, named in ascending order. The characteristic fossils of the Waterlime were collected and figured, *Eurypterus remipes* and *Leperditia alta.* Rominger, as previously stated, combined these with the Dundee, and applied to both the name Helderberg, but recognized an upper and a lower division, thus bringing this word back to something like its original meaning. The Sylvania sandstone he accepted, however, as the probable equivalent of the Oriskany, and hence places the break between his upper division, the Devonian, and the Upper Silurian at the top of this sandstone. It will be shown in this chapter that this break is really higher up and, consequently it lies considerably to the west in our geological map. In the later publications of the Ohio survey, Orton uses the term "Lower Helderberg or Waterlime Formation" and includes in it everything above the Niagara (considering that the Salina is not represented in the Ohio scale), and below his Upper Helderberg. It is exactly this series of beds which has been termed by Lane the Monroe beds. If the original New York Salina is really represented in the geological series of southeastern Michigan, as is very probable, there is no way yet of identifying its beds and separating them from the Waterlime division of the Lower Helderberg. The enormous beds of rock salt and gypsum which occur along the Detroit and St. Clair rivers would strongly suggest the Salina equivalency of these layers, but this cannot be positively asserted until we know the character of the limestones which overlie the Niagara. In Ohio the gypsum beds are underlain by several hundred feet of typical Waterlime dolomite and in New York the same thing occurs.

---

*Michigan, 1873, extracted from Walling's Atlas.

In the later reports of the New York Survey* the Waterlime beds are taken from the Lower Helderberg and added to the Salina. If this practice is followed in this western region, and it has received Orton's sanction for Ohio, the discussion of the geological equivalency of the Monroe beds is simplified, since then they would all be referred to the Salina. In the rearrangement of the New York series by Clarke and Schuchert the Salina and the Waterlime are each recognized and constitute the two lower members of the Cayugan, or Neontaric.

§ 2. General data.

The remainder of Monroe County, eastward from the basal layers of the Dundee, is underlain by the upper beds of this great series. This comprises over two-thirds of the county and includes the entire townships of Whiteford, Bedford, Erie, La Salle, Monroe, Frenchtown and Berlin, nearly the whole of Ash, Raisinville, Ida and Summerfield and one-half of Exeter. It thus forms a belt from eleven to seventeen miles in breadth and extends further eastward beneath

---

*Report State Geol., Vol. I, Geology, 1893.

Lake Erie and Detroit River. The beds strike northeastward as far as Stony Creek, where they turn eastward and, in the case of the lower beds exposed, finally southeastward. The dip of the beds varies considerably in direction and amount. Certain data indicate that from Toledo to Adrian this averages about 35 feet to the mile, but it is not regular, increasing in amount toward the west. This is shown by the narrowing of the outcrops of the beds beneath the drift in the southwestern part of the county and by the inclination of the strata seen in the quarries just over the Ohio line. The upper layers from the county line northwest of Ottawa Lake to Adrian dip at the rate of 56 to 57 feet to the mile. Measured upon the Trenton, which may be assumed to be conformable with the overlying beds, the dip from Monroe to Dundee is about 26 feet to the mile. From Monroe northward the direction of the dip changes from northwest to north and, as nearly as can be made out from the interpretation of the well records at Trenton and Wyandotte, equals 30 to 40 feet to the mile. The breadth of the outcropping belts, beneath the drift, is increased in the northeastern part of the county because of the increased thickness of the beds, and in spite of this greater dip. The Monroe beds lie nearer the surface than any of the preceding formations and are responsible for all the actual natural outcrops. The heaviest covering of drift occurs in the southeastern portion of Erie township, where it is from 90 to 100 feet thick. At the head of Ottawa Lake the highest elevation of the rock surface is attained, about 685 feet above sea level. From this point there is a very gradual slope of the rock surface in all directions, being greatest in rate and amount toward the southeast. In the southeastern corner of Erie township the elevation is about 470 to 480 feet, having dropped over 200 feet in 15 miles, or at an average rate of 13.3 feet to the mile. An inspection of the contours upon Plate I shows, however, that the slope is much steeper over the latter half of this distance, being equal to about 24 feet to the mile.

§ 3. Thickness.

The great breadth of the outcrops beneath the drift, of the Monroe beds indicates that we have a much thicker formation than any previously described. In Ohio the total thickness is 600 feet and borings in Michigan and Ontario indicate that it increases toward the north for a certain distance. In the five Trenton wells the average thickness is 1216 and in the Dundee well it is over 1000 feet. At

Wyandotte, in the well of the Eureka Iron and Steel Works the thickness appears to be 1375 feet. In the Solvay wells, at Delray, it is apparent that none of this thickness has been lost and it may have been considerably increased. Still further north, at Goderich, Ontario, according to Hunt, some 1517 feet of these beds were penetrated without reaching the bottom. Upon Plate V is recorded the section of one of the Monroe deep wells reprinted from Vol. V, which shows that the Niagara was reached at a depth of 700 feet. From the breadth of the outcropping layers and the dip it is estimated that about 200 feet of these beds are represented between Monroe and the base of the Dundee, so that the entire thickness of these beds in the middle of the county is not less than 900 feet. From what has been said, however, and from an inspection of the geological map, it will be apparent that the actual thickness to be penetrated in any given boring will depend upon its north and south position in the county and its distance southeastward from the base of the Dundee.

§ 4. Lithological characters.

So far as they are exposed within the county the Monroe beds consist of a series of gray to drab magnesian limestone (dolomite), embedded in which are strata of oölite, very sandy dolomite, and a friable bed of remarkably pure sandrock. These beds are so distinct, lithologically, that they have been of much service in the deciphering of the geological structure of the county and each will be separately described as fully as its importance seems to warrant. In the following chapter IV on quarries a still more detailed description will be given of the individual beds that make up the series. In general, it may be said that the typical dolomite layers show the normal proportions of lime carbonate and magnesium carbonate; from 50 to 55% of the former and 42 to 43% of the latter ingredient. The amount of alumina and iron together is generally less than one per cent, while the silica, in *insoluble* form, varies greatly at the expense of the carbonates. Bituminous matter is present locally but does not impregnate the rock as in the case of the Dundee. Near the top of the series, where weathered, the rocks become of almost a chalky whiteness and contain gypsum, but ordinarily they are gray to dark drab, sometimes running into a yellowish brown. In the deeper portions of the quarries they are sometimes blue. The rock responds only slightly to cold dilute acid, unless it is powdered, when the effervesence is brisk. In this way the Monroe dolomite is to be distinguished from the Dundee limestone. Fossils are not abundant in the dolomite, except rarely in patches, and they are always in the form of molds, internal or external casts.

The rock layers are generally thin-bedded, rarely reaching one foot and usually less. Toward the lake, near Monroe, the beds have been much disturbed and the rocks shattered. In the Plum Creek quarry of the Detroit Stone and Supply Company, the bedding is described as being almost vertical, but could not be directly observed owing to the water present. North about two miles in the quarry of the Monroe Stone Company, the bedding is typical but the rocks seem shattered. In Monroe there is a tradition that about thirty years ago, one Sabbath morning, an explosion occurred in the bed of the river just above the city, which startled the entire region and very visibly disturbed the layers of rock in the river bed. There is wide-spread evidence that at a much earlier period than the time of the disturbances above referred to, probably while the beds were forming the rocks which compose them were broken into angular fragments and then recemented. Such brecciated beds are seen near Monroe and at Stony Point, and, according to Rominger, Orton, and Winchell, occur all over northwestern Ohio, the islands of Lake Erie, at Goderich and on the island of Mackinac. Thin slabs of dolomite showing ripple-marks and mud cracks occur in the Plum Creek quarries, characterize the Ohio beds, and extend into eastern New York. Immense concretionary bodies with finely laminated structure, regarded by Winchell at the time of the preparation of his first report as organic in their nature, are seen about Monroe and to the northeast. Their great convex surfaces bulge upwards through the floor of the quarry north of Monroe (See Plate IV); they are seen eastward on the lake shore, and are still better shown in the Patrick quarry on Grosse Isle, where they seem to be 12 to 15 feet in diameter in certain cases. It is very probable that they were formed while the dolomitic slime was still soft, through the action of the concretionary agencies which are as yet so little understood.

In the beds underlying Monroe and known only through samples of the well drillings, the dolomites are found to contain varying quantities of a form of calcium sulphate, known as anhydrite. Northward this mineral is found in distinct beds many feet in thickness and associated with pure rock salt, shales and sandstones. The section of the Noble well, at Monroe, as given on Plate V, shows a 230 foot bed of yellowish limestone, briskly effervescing with dilute acid, which was struck at a depth of 100 feet from the surface, or about 300 feet from the base of the Dundee. This seems to correspond in position with a group of limestones, 276 feet in thickness, containing corals, chert, and dolomite beds, reported by Hunt as occurring at Goderich, at the foot of Lake Huron. The series was struck at a depth of 357 feet from the surface and is overlain by 278 feet of dolomite, with thin limestone layers.* Hunt regarded this as an intercalation of Corniferous (Dundee) amongst the beds of Lower Helderberg (Monroe). The overlying dolomite was supposed to be continuous with the Lake Erie beds containing Waterlime fossils. The limestone itself is of the gray non-magnesian variety, rich in fossils, corals and chert. From fragments in the cores Hall identified *Favosites Winchelli* Rom., and *Favosites Emmonsii*, Hall, these being characteristically Devonian. This peculiar limestone series is underlain by dolomite containing gypsum.

§ 5. Lithological history.

It is evident from the variety of rock material represented as making up the extensive Monroe series that its formation must have taken place under widely varying conditions. The sea bottom was subject to repeated oscillations and the shore line advanced and receded, probably several times. Geologically it was a period of unrest, these disturbances in Michigan being but distant ripples from the agitation which brought the Silurian to a close and caused the advance in plant and animal life. The beds of sandrock and the conglomerate of Ohio and Mackinac were formed while shore conditions prevailed. The beds of shale, which occur toward the bottom of the series, represent the muddy accumulations of the off-shore. The beds of dolomite, which comprise the main bulk of the series in southeastern Michigan, seem to have been formed in a shallow, open sea, sufficiently distant from land not to get much sand and mud.† The paucity of fossil remains in such beds led Cordier, Hunt, Ramsey and others, to assign to them a chemical origin. If such a theory is accepted in whole, or in part, then this dolomite *dough* must be regarded as a chemical precipitate, to be described below. The oscillations of the earth's crust occasionally exposed patches of this sea-bottom to the air and sun, which upon drying shrank and gave the mud cracks mentioned as occurring about Monroe, as well as elsewhere. These were later submerged, covered with soft slime and indefinitely preserved. Pressure, carbon dioxide gas and probably a low degree of heat have compacted these soft layers into firm rock.

---

*Geological Survey of Canada, Report of Progress, 1876-77, pp. 221-243.

†Or the climate may have been dry and the land low and the sea shallow so that not much sediment was formed. L.

The conversion of calcium carbonate into the double carbonate of calcium and magnesium, known as dolomite, has as yet received no entirely satisfactory explanation. The geological occurrence of dolomite gives no warrant for the theory of Von Buch that it represents limestone, in which some of the calcium has been replaced by magnesium, through the agency of magnesia vapors rising from beneath. Neither can it be maintained that thousands of square miles of heavily bedded dolomite have resulted from the action of percolating spring waters carrying magnesium salts in solution. Still less probable is the theory that the dolomitization is due to the action of molten magmas from the interior of the earth which have come in contact with limestone beds. In sea water there occur considerable quantities of magnesium chloride (10.878 parts) and magnesium sulphate (4.323 parts), in every 100 parts of the total salts, according to the analyses of Dittmar. By experiment it has been found that these salts, under high pressure, and above the boiling point of water, can convert limestone into genuine dolomite. An analysis of coralline limestone from the elevated coral island Matia, one of the Society group, according to Dana (Corals and Coral Islands, 1872, p. 357), gave 38.07% of magnesium carbonate, showing it to be in reality dolomite. Ordinary coral contains from 95 to 98% of calcium carbonate, with only a slight amount of magnesium carbonate. Dana concludes that this introduction of magnesium into the composition of the coral has taken place apparently in the sea water at ordinary temperatures and without the agency of any mineral waters except those of the ocean. "But the sand or mud may have been that of a contracting and evaporating lagoon, in which the magnesian and other salts of the ocean were in a concentrated state." These conclusions of Dana are accepted by Neumayr* and probably represent the consensus of geological opinion at the present time.

October 28th, 1844, Cordier deposited with the French Academy of Sciences a sealed packet, which after his death was opened and found to contain a paper entitled "De l'origine des roches calcaires qui n'appartiennent pas au sol primordial."* In this the chemical origin of the great bulk of our limestones and dolomites is maintained, the carbonates being derived from the reaction of carbonate of soda upon the chlorides of calcium and magnesium in sea water. The supply of sodium carbonate he believed to be derived from the decomposition of feldspars, from alkaline springs and from plutonic emanations. Some three years before this information was made public, Hunt had published an elaborate account of his experiments on salts of lime and magnesio,† under the title "On Some Reactions of the Salts of Lime and Magnesia, and on the Formation of Gypsums and Magnesian Rocks," in which he had arrived at about the same conclusions. The source of the carbonate of soda, in all cases, he considered to be decomposing feldspathic minerals of the sedimentary rocks and the argillaceous beds are the correlatives of the limestones. The conclusion reached in this paper (p. 383) is that

---

*Erdgeschichte, 1886, p. 590.

> "Dolomites, magnesites and magnesian marls, have had their origin in sediments of magnesian carbonate formed by the evaporation of solutions of bicarbonate of magnesia. These solutions have been produced by the action of bicarbonate of lime upon solutions of sulphate of magnesia, in which case gypsum is a subsidiary product; or by the decomposition of solutions of sulphate or chloride of magnesium by the waters of rivers or springs containing bicarbonate of soda. The subsequent action of heat upon such magnesian sediments, either alone or mingled with carbonate of lime, has changed them into magnesite or dolomite."

Hunt insists that calcium chloride must be absent, whatever the reaction, and that isolated and evaporating basins are indispensable conditions for the formation and deposition of magnesian carbonate.‡ An analysis of waters from the equivalent of these Monroe beds, in Western Ontario, at Chatham, Petrolea and Bothwell shows them to be derived from a bittern, "the result of the evaporation of the waters of an ancient sea."

One of the most recent discussions of the question is contributed by Dr. E. Philippi, of Berlin, in a paper entitled, "Ueber einen Dolomitisirungs vorgang an südalpinen Conchodondolomit."§ The author believes that dolomites in many instances, at least, result from a *leaching* of a lime rock which already contains a certain quantity of magnesium carbonate. The theory is based upon the supposition that the carbonate of lime is more readily dissolved than the carbonate of magnesium, and hence that under proper conditions more of the former would be removed. The result of this would be to produce a rock which would show relatively greater and greater quantities of magnesia until the normal proportion of lime and magnesia might be attained. There is no reason to think that this theory can have any application in the case of our Monroe beds, where 900 to 1,000 feet of practically horizontal layers are evenly dolomitized. It would necessitate the destruction of unsupposably great masses of limestone, unless there is assumed to be present, from the first, considerable quantities of the magnesium carbonate. If such supposition is made then the difficulty of accounting for this carbonate is as great as is that of the original question. In ordinary corals which contribute so largely to the formation of limestones, there is present but a very small quantity of magnesia, *Isis hippuris* yielding Forchhammer the relatively large amount of 6.36%. Upon the supposition, however, that the magnesium carbonate is but one-tenth as soluble as the calcium carbonate, it is evident that in the process of leaching such a stone, the magnesium would have practically disappeared before the normal proportions for the two had been attained. There is no apparent agreement upon the part of supposed authorities however, in regard to the relative solubility of these two carbonates. Bischof found that a prolonged action of water, charged with carbonic acid, upon a limestone containing 11.54% of magnesium carbonate, dissolved out 4.29% of its calcium carbonate, but without appreciably affecting the magnesium.* With water containing three to four grams of magnesium sulphate to the liter, Hunt found that there would be dissolved 1.2 grams of carbonate of lime and 1 gram of carbonate of magnesia to the liter.

---

*C. R., Feb. 1862, pp. 293 to 299.

†American Journal of Science, 2d series, Vol. XXVIII, 1859, pp. 170-187, 365-383.

‡Chemical and Geological Essays, 1891, p. 92.

§Neues Johrbuch für Mineralogie, Geologie und Palæontologie, I Band. Erstes Heft, 1899, pages 32 to 46.

From his researches Dittmar concluded that in sea water carbonate of magnesia is far more freely soluble than is carbonate of lime. In all the above cases the water contained different ingredients but nothing which might not be present in the waters percolating through a bed of limestone. Additional evidence against the application of this leaching process to our Monroe beds is furnished by the complete conversion into dolomite of the granules of the bed of oölite. These were originally calcareous and, judging from the Great Salt Lake oölite now in process of formation, have not been appreciably reduced in size. There has taken place here a partial replacement of the calcium carbonate with the carbonate of magnesium, this action occurring at the time of the formation of the beds and in sea water strongly charged with magnesium salts.

---

*Lehrbuch, Vol. II, p. 1176. See also Treadwell and Reuter in Zeits. für Anorganische Chemie, Vol. XVII, 1898, pp. 170-204.

It seems necessary to conclude from these and still other considerations that a great inland basin had been formed in which the waters were greatly concentrated, while the open sea retained its normal composition. Hunt explains the intercalation of Corniferous amongst the beds of the Salina, by assuming that in the ocean the life had advanced into the Corniferous age, while that in the basin itself was still Silurian. A temporary influx of the sea into a part of this basin would bring in the higher forms and establish a new set of conditions, favorable for the growth of corals and the production of limestone. The cutting off of the direct supply from the ocean would in time exterminate the life in this particular region and by the opening of direct communication with the remaining interior basins, former and older geological and palæontological conditions would again prevail. Such basins would supply the necessary conditions for the deposition of gypsum, or anhydrite, and for the formation of rock salt found further north. Through the continued concentration of the water contained, after the point of saturation had been passed, there would be deposited a layer of calcium carbonate followed by one of calcium sulphate and later one of rock salt.* As evaporation progressed the water would be withdrawn from the margins of the basin and the deposits of salt would not extend shoreward as far as those of the lime carbonate and calcium sulphate. For this reason we find beneath Monroe more or less anhydrite, but no rock salt until we pass further north, in which direction numerous beds are developed, some of them attaining surprising thickness beneath Detroit. The deeper portions of the original evaporating basin then lay to the north of Monroe county, and the shore to the south. After the deposition of most of the calcium carbonate, calcium sulphate and salt there would remain in the central and deeper portions of the basin a solution, rich in chlorides of calcium, magnesium and sodium, and consequently intensely bitter to the taste. If complete evaporation took place these salts would crystallize, but if not the bittern containing them would impregnate thoroughly the beds formed later. Percolating waters would subsequently take up these salts again and give rise to the highly charged mineral waters that characterize the central portions of this great Silurian basin.

---

*See Vol. V, Geol. Survey of Mich.,Pt. II, pp. ix to xix. "The origin of Salt, Gypsum and Petroleum," Lucius L. Hubbard.

Description of special beds.

§ 6. Sylvania sandstone.

On account of their economic and stratigraphic importance it seems desirable to describe somewhat in detail two sets of strata which mark well defined horizons in the beds of dolomite. The chief characteristics of the latter rock will be presented in the following chapter IV upon quarries. Of these included beds the thickest, most important and most readily recognized one is the Sylvania sandstone.

This has been named from its occurrence southwest of the village of Sylvania, Ohio, where it has been quarried for the manufacture of glass. It enters the southwestern corner of Whiteford township (Sec. 5, T. 9 S., R. 6 E.) as a narrow belt scarcely more than one-half mile in breadth, owing to its steep westerly dip. It strikes northeastward across the county, broadening gradually to about four miles near the center, as seen upon the map (Plate I). Toward the Raisin, northeastward across Raisinville, the bed seems to narrow to less than a couple of miles as far as southwestern Ash, then turns to the east and maintains a breadth of two to three miles across Ash and Berlin townships. Upon entering Whiteford, from Ohio, it is covered by twenty to twenty-two feet of surface materials, which are reduced to ten feet, or less, in Sec. 28. Drift fragments of the harder portions of the rock occur in the vicinity, scattered over the fields, in the N. E. ¼, S. E. ¼, Sec. 5; N. E. ¼, N. E. ¼, Sec. 32; N. E. ¼, N. W. ¼, Sec. 33 and in the N. W. ¼, N. E. ¼, Sec. 29. From Sec. 28 the drift covering increases northeastward to twenty and then to thirty feet or more. In Raisinville the rock comes nearer the surface and forms the bed of the Raisin for a considerable distance. At the ford, near Grape, heavy building blocks for foundation walls have been removed. Where the rock is less coherent it has been scooped out by the river and only the harder strata appear in the ledges exposed during stages of low water. Just below the ford between claims 494 and 408 (South River Raisin), there is a bed of brown dolomite capped by six to ten inches of chert, while at the ford itself, blocks of sandstone were found which are either in place or have been shifted but a short distance. Opposite claim 275 (South River Raisin) dolomitic sand rock occurs.

The only natural outcrop of this sandstone occurs in the southwest quarter of Sec. 2, T. 6 S., R 8 E. (Claims 493, 484, North River Raisin.) Here extending over an area of eight to ten acres, to the north and west of the "Blue Bush Cemetery" the rock is directly exposed or covered by only a few inches of soil. Beneath an area of sixty acres the surface covering is said to be but two to three feet in thickness. Several pits have been opened exposing the bed to a depth of 12 to 30 feet, from which sand has been taken for shipment. In the eastern part of Ida township a trough is developed in the upper surface of this soft bed, extending its entire distance northeastward, as shown by the contours on the map (Plate I). The drift covering over the deeper portions of this trough in Ash and Berlin varies from 30 to 35 feet. The highest elevation attained by the bed is 673 feet above sea-level in Secs. 28 and 32 of Whiteford. The drop is gradual in the direction of the strike, giving an altitude of 610 feet A. T., in Ida, 613 to 588 A. T. in Raisinville and, finally, in Berlin a minimum of 560 feet A. T., or 13 feet below the level of Lake Erie.

Where it enters from Ohio the bed is probably not over 30 feet in thickness, but it increases gradually toward the northeast. At the cranberry marsh of Mr. C. W. Everett (S. E. ¼, Sec. 24, Summerfield) it showed a thickness of "40 to 50 feet," overlain by thirty feet of blue limerock (dolomite). In the deep well at Ida (N. E. ¼, Sec. 3) there were 45 feet penetrated. The breadth of the outcrop along the Raisin would indicate about the same thickness. The greater breadth of the belt in eastern Ida, western La Salle and southern Raisinville, does not seem to be due to increased thickness but rather to the position of the beds. At the sand pits, above referred to, three sets of cores have been taken out, giving a thickness of about 60 feet. There is a capping of four feet of a laminated dolomite here, which has escaped the general erosive agencies, showing that practically the entire thickness is represented by these cores. To the northwest, about three miles, at the Woolmith quarry (S. E. ¼, Sec. 29, Exeter), borings give the bed a thickness of 50 feet. The bed was penetrated at Gibraltar, Horse Island, in a 130 foot well belonging to Edmund Hall, but the record of the thickness could not be obtained. It is a matter of geological, if not economic interest, to know that this bed continues northward giving a thickness of 95 feet at Trenton, 130 feet at Wyandotte and, in the ten Solvay wells at Delray, an average of 99.4 feet.

Beds of essentially similar sandrock, but carrying considerable dolomitic matrix, occur both above and below the main bed, but separated from it by layers of dolomite. These secondary layers may be mistaken for the Sylvania proper, as was done by Rominger, and its thickness underestimated.* In the Davis quarry one and one-half miles west of the village of Ida (N. E. ¼, Sec. 4), a series of drill cores gives a compact white sandrock six feet thick, at a depth of 25 to 31 feet. Beneath this lies a silicious dolomite which caps the main bed struck at Ida. At the Lulu quarry (N. W. ¼, Sec. 16, Ida) one foot of similar sandrock is exposed with dolomite above and below. The same rock is seen in the floor of the Cummins' quarry (S. E. ¼, Sec. 2, Whiteford). At the mouth of Willow Run a layer of sandrock occurs which might easily be mistaken for the Sylvania, except that it is much coarser than the typical sandstone. It is overlain and underlain by beds of silicious dolomite, as seen in the Raisin bed and as indicated by adjoining well records.

Owing to the limited number of natural exposures the tracing of the Sylvania across the county had to be done largely from records of farmers and drillers. Such records were not always as abundant and definite as was desired and the breadth of the outcrop beneath the drift can be regarded as only an approximate one. Certain common expressions were found to characterize the bed in these records collected and much importance attached to them. The loose sand so frequently pumped from the wells over this belt was said to resemble "snow," "flour," "salt," "granulated sugar." The bed itself furnishes water throughout its extent and a very common report was that a thin crust of the bed had only to be punctured, when the water could be pumped or would rise to the surface. In numerous instances the sand-pump had to be used first before any considerable quantity of water could be obtained, thus testifying to the incoherent nature of the bed. Except in a few deep wells the bed is not entered far, so that we have comparatively few records of its thickness. In such cases it is said to cut the drill very badly, so that it would require very frequent sharpening. The reason for this will be apparent when the form of the individual grains is described. Some typical descriptions will serve as samples of the data, by means of which the bed was located upon the geological map.

Information secured from Barney Gay, a local driller of South Rockwood. At John Strong's S. E. ¼, Sec. 8, Berlin, struck 15 feet of sand, "white as snow," went five feet in five minutes, and pumped sand for two weeks. At the blacksmith shop in the village, at a depth of 18 feet, "struck a funny kind of stuff," which was white. From all the wells in the neighborhood he secures white sand. Sometimes it has above it a hard crust. At the place of Joseph Borrow (S. E. ¼, S. E. ¼, Sec. 17, Berlin) it is twenty-four feet to a "shell-like rock," below which the drill drops four to six inches. This rock is a dark lead color. Before water will flow there must first be pumped out a snow-white sand of which there may be two to two and one-half feet. Has pumped out two to three wagon-loads. At Peter Donelly's (S. E. ¼, N. E. ¼, Sec. 19, Berlin) it is 32 feet to rock. Dug 14 feet and drilled 16 to 18, when the drill dropped three to four inches. The water rose into the dug portion and "spewed" white sand, covering the bottom to a depth of several inches.

---

*Geol. Survey of Mich., Vol. III, Pt. I, pp. 27-29.

Charles G. Peters, S. W. ¼, Sec. 8, Berlin (T. 5 S., R. 10 E.). Has two flowing wells, each 28 feet to a "shell-rock." In the well at the house the drilling was stopped for the night, no water having been secured. The next morning the water was found to be flowing, having brought up eight to ten bushels of sand, "white as paper," and giving the appearance of a snow bank about the mouth of the well. In the well in the woods he did not secure this sand. although a gray variety was struck. At the N. E. ¼, N. E. ¼, Sec. 18, Berlin, he put down a well in which rock was struck at 30 feet and entered 32 feet. It wore the drill considerably. In color it was "grayish, or dark like, whiter on drying." Considerable sand had to be pumped out, when the well flowed until a well was drilled at Howard Valrance's (N. E. ¼, Sec. 17, Berlin), since which time the water has had to be pumped. Still another well was put down in S. E. ¼. S. E. ¼. Sec. 7, Berlin (T. 5 S., R. 10 E.), at which place rock was struck at 30 feet. A very hard shell was first reached upon which the drill "rang like a kettle," and beneath this lay the same sandrock.

Charles M. Hood, N. W. ¼, S. W. ¼, Sec. 13. Ash. Here it is 32 feet to rock. Water rises to within four feet of the surface, is hard and contains iron. Just below the clay a hard "crust," a few inches thick, is struck. This has only to be punched through and the sand pump put in to secure water. From this well there have been pumped several wagon boxes of sand, which is used for scouring. When wet it packs very firmly. Has put down wells at eight different places in the neighborhood in each of which this same sand was obtained.

C. B. Loranger, N. W. ¼, Sec. 26, Berlin. Flowing well of sulphur water, with some iron and, at times, oil. After entering rock two feet a white sand was reached, looking "like flour." A few rods east is another well from which much sand has been pumped.

Augustus Dobberstein, S. W. ¼. N. W. ¼, Sec. 29, Ash., 35 to 36 feet to a very hard rock. Water stands 10 to 12 feet from surface and is considered "soft." A barrel of the water will sometimes yield a half barrel of white sand. This sand cut the drill badly and filled in the hole so as to prevent further drilling. Well becomes completely filled with sand and has to be reopened.

Peter Stumm, N. W. ¼, N. W. ¼. Sec. 32, Ash. 32 feet to a solid rock, above which water was secured. There was a "soft stuff" just above rock, which felt gritty on the augur. Jabbed through a crust two to three inches thick, when water rose rapidly in the well, standing about seven feet from the surface. The drill was cut badly and upon entering the rock "bounced."

Michael Strobel, N. E. ¼. Sec. 15, Ida. Rock was reached at 27 to 28 feet and entered 20 feet. An attempt to take out a core failed. No casing was put in and the hole filled with sand.

The chief characteristics of the Sylvania sandstone will be inferred from the above records. Typically it is a fine grained, sparkling, snow-white sandrock of remarkable purity. Usually it is very friable and incoherent, readily crumbling into sand in the fingers, or under the action of a drill. This is due to the lack of cementing material present with which to bind together the grains. Locally, considerable dolomitic cement may be present, forming a compact white sandstone, from which good cores may be removed by means of the "diamond drill." The beds exhibit only coarse stratification as observed at the pits and along the Raisin. At the Sylvania quarries, however, in some of the beds, there is quite a distinct lamination seen on weathered surfaces. Fossils are rare and very poorly preserved for the most part. Fragments of the sandstone taken from the Raisin near Grape furnished traces of trilobites, corals, brachiopods, lamellibranchs and gasteropods, but in an unsatisfactory condition for positive identification. At the outcrop the upper strata, to a depth of 8 to 10 feet, are discolored by percolating surface water. The stain is said to be due to organic matter, however, and not to iron. The following analysis of the rock at this locality is kindly furnished by W. H. Cowles, of Detroit, and shows the composition before it has been subjected to the washing process which prepares it for glass manufacture:

Silica	96.50%
Calcium carbonate	1.50
Magnesium carbonate	1.04
Iron oxide	.00
Sulphuric acid loss and undetermined	.76
Loss on ignition	.20
	100.00

Under the low-power of the compound microscope the individual grains, instead of being rounded, exhibit sharp points and edges, with plane faces. A close inspection shows that a very large proportion of them are, in reality, short hexagonal prisms, terminated at one or both ends with a hexagonal pyramid. They are thus more or less perfect quartz crystals. Examined with polarized light, a still more interesting fact is developed. The body of each minute crystal is an ordinary rounded sand grain, about which a thin shell of quartz has crystallized so as to give it optical continuity; as is evidenced by the fact that both granule and shell extinguish simultaneously, when revolved between crossed nicols. In the central granule Prof. C. H. Smyth, Jr., has identified crystalline inclusions of hornblende, apatite, tourmaline, rutile and zircon. Fluid inclusions, with bubbles, can also be seen with high power, showing that these grains do not differ from ordinary sand grains of the sea or lake shore. Upon the outside of the crystals are developed sparingly, minute rhombohedrons of calcite, or dolomite, probably judging from analysis above, the latter.

Perfect quartz crystals from the insoluble residues of limestones had been described in the early part of the century but their real nature remained unknown for many years. In 1880 Sorby described such sand grains as consisting of an angular or rounded quartz grain, with a secondary addition of crystallized silica, giving crystalline continuity.* In the New Red Sandstone of Penrith, he found upon the surface of the enlarged grains impressions due to the interference of contiguous grains. "Thus proving conclusively that the deposition of crystalline quartz took place after the nuclei were deposited as a bed of normal sand." (p. 63). In the case of the Vosges sand Daubrée had recognized such enlarged grains and believed them due to the local action of heated water. In the Fifth Annual Report of the Director of the U. S. Geol Survey,* Irving describes and figures similarly enlarged grains from our American rocks, showing that the secondary silica may serve as a cement and give rise to quartzites from sandstone. His investigations prove

---

*Quarterly Jour., Geological Society, Vol. 36, p. 62.

> "That most if not all of the ancient quartzites, as well as many of the quartziferous schists, are simply fragmental rocks composed in the main of the original fragmental material—unaltered save by some of the ordinary metasomatic processes—cemented together by a siliceous cement of secondary origin. This siliceous cement forms the only part of the rock that has crystallized *in situ*, the more or less intricate interlocking of its areas and its common optical continuity with the original quartz fragments giving rise to the deceptive appearance of complete original crystallization" (p. 221).

The discussion of the secondary enlargement of quartz grains was continued by Wethered in 1888,† and theories of their origin presented. He concludes that they cannot represent detrital matter, since there is no evidence of wave action, that they could not have crystallized directly from a solution of silica and that they are not the result of crystallization of amorphous or chalcedonic silica, but that they do represent additions of crystalline silica to a rolled or broken quartz crystal. This secondary silica he regarded as having been

> "extracted from solution by the molecular affinity between the silica of the detrital quartz and the silica in solution" (p. 196).

With the results of these investigations in mind let us frame an explanation of the formation of this rather remarkable bed of sandstone. The stratification noted would prove that it was originally deposited in water, and the presence of marine forms in fossilized condition, proves that this water was the sea. Sand accumulates only in the region of the shore.‡ To account for the spreading of a shore deposit over such wide areas it is necessary to assume that the shore line was not stationary, that it was advancing landward, owing to subsidence, thus establishing shore conditions successively over wider and wider areas. Branner describes a beach deposit in Brazil, consisting of cobbles, pebbles and sand and attaining a thickness of ten feet, which was thus made to cover thousands of square miles.* In this case, however, an elevation was in progress and the deposit attained only the ordinary thickness of beach material. The gradual subsidence of the sea bottom in southeastern Michigan, while the materials for the formation of the bed were accumulating, would permit a considerable increase in thickness. The lower strata would contain coarser particles, deposited while the shore was nearer; the upper strata would consist only of grains which were small enough to be carried some distance seaward by waves and currents. The silica for the sand grains was probably derived indirectly from the ordinary crystalline rocks and the grains were rounded and assorted by wave action. The mud was carried seaward and there should exist somewhere a bed of shale, the correlative of the Sylvania sandstone unless it was derived from the disintegration let us say of the Potsdam sandstone. Dolomitic slime derived from the disintegration of calcareous organisms, or precipitated directly from the sea water as previously explained, might be deposited with the sand grains and serve as a matrix. The proportion of sand and slime would determine whether there would be formed a dolomitic sandrock or sandy dolomite, such as underlie and overlie the Sylvania proper. Finally, when the shore line had sufficiently retreated the supply of sand would fail, only the formation of dolomite would continue and the epoch of the Sylvania would have closed. Subsequent to the complete formation of the bed, percolating waters, rich in alkaline salts and holding relatively larger quantities of silica in solution, saturated the loose sand, and about each grain a thin layer of crystallized quartz was deposited, owing to the "molecular affinity between the silica of the detrital quartz and the silica in solution." Experiments upon fragments of crystals suspended in saturated solutions of the same substance have shown that the crystalline accessions invariably yield crystalline, and hence optical, continuity with the original fragments. The molecules of the secondary silica simply dropped back into the places occupied by those lost from the original crystal fragments from which the sand grains were fashioned. The character of the percolating water soon changed, otherwise there would have been formed a quartzite as soon as the silica deposited began to firmly unite the grains. That the secondary enlargement of the grains took place after the formation of the beds is conclusively proven by an examination of those embedded in the adjoining dolomites. When fragments of these are digested in hot acid in order to remove the carbonates, the sand thus obtained is snow white and, under the microscope, shows also secondary additions of crystallized silica. Instead of getting perfect crystals, however, the surfaces are seen to be roughened with imprints of rhombohedrons of minute dolomite crystals, against which the crystals of quartz have grown.

---

*1885, pp. 181 to 242.

†Quart. Jour., Geol. Soc., Vol. 44, pp. 186 to 199.

‡i. e. in the littoral belt, but sand as fine as that of Sylvania may be carried a good way by currents. L.

---

*"The supposed Glaciation of Brazil." Journal of Geology, Vol. I, No. 8, 1893, pp. 753-772.

The upper strata of the Sylvania sandstone, to the north of the Raisin, are about 70 feet below the base of the Dundee, this space being occupied by dolomites, more or less silicious, which cannot be separated lithologically, or palæontologically, from those lying beneath. The quarry rock at Ottawa Lake, the "sinks," Lulu, Ida, Raisinville and Woolmith, is all derived from these beds which intervene between the Sylvania and the Dundee. Thus embedded in the Monroe beds there is no reason yet known for assigning to it any different geological age than that of these Monroe beds themselves. At the time of the Newberry survey of Ohio the Sylvania was supposed to separate the Lower from the Upper Helderberg formations, and with an entire absence of fossils, it was very naturally correlated with the Oriskany sandstone of New York. Rominger regarded it as occupying this same geological position in our Michigan series and its correlation with the Oriskany as very probable. In his Biennial Report of 1860 and in his map of 1873, Winchell includes the bed in the Corniferous. In 1893 Orton first pointed out the fact that this bed in Ohio is overlain by typical Waterlime strata* said to be 200 feet in thickness. These beds are seen in the Sylvania quarries, lying to the west of the sand pits, and one mile farther north at the Cooper quarry, N. E. ¼, N. E. ¼, Sec. 18, T. 9 S., R. 6 E. The Sylvania sandstone must be regarded as part of the Waterlime group of the Salina.

§ 7. Oölitic beds.

Several beds of dolomitic oölite are known to occur, embedded in the dolomitic limestone. The upper one lies about 45 feet above the top of the Sylvania and hence about 25 feet below the base of the Dundee. It varies in thickness from three and one-half to four feet, as seen at the Woolmith quarry and in the adjoining excavation on the place of John Hoffman. The lowest bed exposed lies below the Sylvania at a distance of about 100 feet and in the neighborhood of 200 feet below the Dundee, giving a well defined horizon. This bed is most typically developed on Plum and Stony creeks as a light brown absorbent stone, gritty to the feel and showing a thickness of twenty inches to two feet. To the southwest of Monroe the structure becomes somewhat modified and obliterated and grades into a bed of brown dolomite, five to six feet in thickness, known locally as "bastard limestone."

---

*Geol. Surv. of Ohio, Vol. VII, pp. 17-18. The correlation of this part of the geologic column is just now a subject of lively controversy. See two recent papers by H. S. Williams, pp. 333-346, and Charles Schuchert, pp. 241-332, of Vol. XI, Bull. Geol. Soc. of America.

Occupying the crest of the ridge it has been found in enough places in the county to permit the approximate tracing of it upon the geological map, whereas this was impractical for the uppermost bed. It enters the county from Ohio in Sec. 4, Whiteford (T. 9 S., R. 6 E.) and is first seen in the N. E. ¼, N. E. ¼, at a small quarry belonging to Stephen Young. Passing northeastward it is seen in the excavation along the roadside belonging to Nelson Bush (S. W. ¼, S. E. ¼, Sec. 25, Whiteford) and again some 80 rods eastward on Halfway Creek. It is next seen in the quarries about Little Lake in Bedford township. The best exposure is in the quarry on the farm of Mrs. White, where it is overlain by a few inches of loose dolomite. Upon the Dunbar farm to the northwest (S. W. ¼, S. W. ¼, Sec. 10, Bedford), the oölite is struck in a small field quarry about 100 yards east of the residence. At the center of Sec. 32, La Salle township, it was found in a small quarry belonging to W. W. Green, and again upon Otter Creek, claim 538, South River Raisin, where it is much compacted, light brown in color, having a gritty feel and might easily be mistaken for a sandstone. Still striking northeastward it appears in the bed of Tamarack Creek (property of Dennis Navarre, claim 498), and on the south bank of Plum Creek, claims 498 and 230, South River Raisin, in the Navarre quarries. The dip here is local and equals about six to seven feet in one hundred. Some 200 yards up the creek local flexures bring the bed to the surface, where the dip is 4° toward N. 22° W. At Brest, on Stony Creek, property of Mrs. Mary Emerson (claim 532, North Stony Creek), the oölite occurs in the best condition for study. The granules are very generally spherical and readily separate from one another in the fingers. From this point the bed strikes eastward and curves to the southeast, where it forms a submerged layer at Stony Point, Lake Erie. The gravelly beach from Stony Point to Point aux Peaux contains many partially worn fragments of this bed.

As seen on Stony Creek the component grains of the oölite are very regularly spherical and average about one-fiftieth of an inch (0.4 millimeter) in diameter. The cementing material is dolomite, which has formed a thin layer over the granules, showing minute crystal faces when examined with the magnifier. These granules have a concentric structure, being made up of a series of delicate, concentric, spherical shells. Occasionally when the granules are broken across some of their central layers drop out, giving them the appearance of having possessed a nucleus of some different material. With cold, dilute hydrochloric acid they effervesce slowly at first, but as they fall to pieces, the action becomes more rapid. When a considerable number are thus dissolved the acid becomes clouded and there settles to the bottom a dark brown, bituminous sediment. When single granules are treated with strong acid upon a glass slide, under the microscope they are seen to disintegrate into an immense number of minute, irregular dolomitic crystals, which dissolve only very slowly. There remains behind only the brownish slime and a few irregular birefractive fragments, none of which can, however, be regarded as a nucleus about which the concentric shells could have formed. In thin sections there is no trace of a solid nucleus, such as a sand grain, although the central portion sometimes appears darker and sharply defined from the remainder of the granule. These darker centers are more frequent in the Plum Creek sections than those from other localities from which material was sectioned and are apparently due to an accumulation of bituminous matter. Their diameter varies from one-sixth to three-fourths of that of the granule itself. Occasionally the central portion is lighter colored by transmitted light and a band of darker material lies outside, while in some instances a light band intervenes between the darker central portion and an outer darker band. In the preparation of the thin sections the central portion has occasionally dropped out, showing a surface of weakness between certain layers. When magnified the granules are seen to be made up of a great number of interlocking birefractive crystals of dolomite, which become well defined rhombohedrons, with their curved faces, about the outside surfaces of the grains. Toward the centers the crystals are invariably smaller. Except for this difference in color and size of the component crystals there is a very little trace of concentric structure when viewed with the microscope. Where the central mass has dropped out the margin appears rough.

Rarely dolomite crystals are arranged as a single concentric layer. There is no trace of a radial arrangement of the crystalline particles in any of the sections.

As has been stated the oölite shows considerable modification in its various outcrops and, indeed, considerable at the same locality. Typically it is made up of an immense number of subspherical bodies, cemented more or less firmly, and having the appearance of a mass of fish eggs, from which it derives its name. Upon Plum Creek these corpuscles are smaller than those seen at Brest, and the structure is not so apparent to the naked eye. Under the hand magnifier the darker central core is very conspicuous in all those which happen to be broken across near the center. Mingled sparingly with these spherical to ellipsoidal bodies are others which have about the same, or somewhat less, diameter but with a length of two to three diameters and are either straight or slightly curved. Their ends are rounded and they have the appearance of short, blunt sticks. Except for this difference in shape and bulk they exactly resemble the other bodies. At the White quarry, Little Lake, the granules are nearly all flattened and elongated to a length of about two diameters, while at the Dunbar quarry near by, the flattened forms are abundant with large numbers of the small subspherical type filling the spaces. The central darker core, with the outer lighter shell, gives evidence of the same structure as that described above. Under the microscope, in thin sections, they exactly resemble the structure of the more nearly spherical forms and they behave similarly with the acid. Still a third type of structure occurs in the oölitic rock, shown most beautifully and typically at Stony Creek and in the Dunbar bed, where it comprises nearly fifty per cent of the rock. These are flattened, tongue-like masses, varying much in size, from that of the flattened granules above mentioned to heavy masses four inches long, by three wide and one inch thick. Ordinarily their thickness varies from one to two millimeters, but their length and breadth are more variable, usually falling within five to ten millimeters. They are arranged in the rock with their flat faces approximately parallel with one another and with the bedding. They usually show evidence of having been broken into fragments and partially recemented, testifying to the disturbances which gave rise to the breccia in the adjoining beds and to the fact that they were *brittle* when the disturbances occurred. Their edges and corners are rounded, their surfaces somewhat undulating frequently showing rounded tubercles and irregular ridges. The smaller the bodies the more irregular and tubercular they become, unless, indeed, there are several types of these to be distinguished. Two hand specimens collected from Stony Creek and one from Bush's quarry, in Whiteford, show the portion of the bed sampled to be made up almost exclusively of this kind of material. These forms might easily be mistaken for frondescent *Stromatoporoids* or *Bryozoa*, so far as their external appearance is concerned, but in thin section they reveal none of the structure of these groups. Dissolved in acid they yield considerable bituminous sediment. Under the microscope they are seen to consist of a dense, interlocking mass of birefractive dolomite crystals, sometimes stained more or less toward the center.

It is evident that these three types of structures were all deposited simultaneously. It is very probable that they were *formed* simultaneously and not far from where they now occur. From their similarity in structure and composition and from their tendency to run together through intermediate forms, it is very probable that they were all formed by the same, or related agencies. The stratification of the bed and its gradual passage into dolomite, with marine fossils, shows that the accumulation took place in the sea. From the discussion which has preceded, it must be inferred that this sea was an inland one and rich in chlorides of sodium, magnesium and calcium. Any explanation of the formation of one form should, obviously, account for the formation of the others. The commonly accepted theory for the origin of the subspherical bodies of a typical oölite, viz., sand grains held in suspension by currents in a solution saturated with calcium carbonate, from which there are deposited concentric layers, will not apply here. In the first place there are no such foreign nuclei present and in the second, this explanation could not apply to the elongated and frondescent bodies. Through the kindness of Prof. I. C. Russell we have had an opportunity to examine some oölitic sand now forming about the shore of Great Salt Lake, and have found it surprisingly similar to our Monroe county product. It is made up of subspherical granules very largely, which average in size the same as those of our Plum Creek material, but ranging as large as those noted from Stony Creek. They are grayish white in color, consist of calcium carbonate, and show a darker central core with a lighter outer band when broken open. Occasionally they are stained with blue or red coloring matter. Exteriorly they are smooth and polished, the larger ones looking like porcelain. Mingled with these bodies are numerous stick like forms, straight or slightly curved, with rounded ends, looking like magnified *bacilli*. Their diameter is less than that of the average subspherical forms, about equals that of the smaller, while the length ranges from two to five or six diameters. These have the same composition and external appearance as the others, including the occasional staining. Much less frequently than the rods, there occur irregular flattened masses, considerably larger than the other forms, with rounded edges and corners and carrying upon their broader surfaces small "tubercles." These are very similar to the structures so abundant at Stony Creek and at Little Lake and Bush's quarry. In the Great Salt Lake oölitic sand none of the larger mases described are represented in the samples. It is possible that these are present in the water of the lake but are not cast upon the shore by the waves, or only the smaller forms of this type may be forming. When dilute acid is applied to any of these bodies the effervescence is very rapid and the layers of calcium carbonate are quickly dissolved, leaving behind what appears as a nucleus in each case. An examination of this with the microscope shows a whitish, porous, brittle mass, having the general form of the spheroid or rod from which it was derived. The material shows no double refraction and refuses to be acted upon by even strong acid. About it there appears to be more or less slime with fragments of irregular crystalline fragments. In some cases a relatively good sized, rounded, quartz grain occurs. If we can assume that the nuclear body is organic, that the crystalline particles are not essential but only incidentally or accidentally present; then the Salt Lake oölite is practically identical with that of our Monroe county bed and they have both been formed under the same conditions and by the same agencies. In the latter granules we find the same crystalline fragments, but the organic structure is represented by only the bituminous matter and there is no apparent nucleus upon digestion with acid.

In the fall of 1891 Dr. A. Rothpletz, of Munich, visited the shore of Great Salt Lake and made an examination of the conditions under which the oölite is forming. He found that which had not yet been washed up from the shore bottom to be partly covered with a bluish-green mass of algæ in which he recognized colonies of *Glœocapsa* and *Glœthece*.* These forms secrete large quantities of calcium carbonate in form of rounded tubercles, which are often massed together in larger irregular tubercular masses, inclosing dead alga-cells. In dissolving the oölitic granules of the beach in very dilute acid he was able to identify the dead and crumpled *Glœocapsa* cells. The rods and tubercular masses yielded similar cells, the former more abundantly than the oölitic grains. He concludes that

---

*Botanisches Centralblatt, Nr. 35, 1892. Translation in American Geologist, Vol. X, No. 5, 1892, pp. 279-282.

> "The oölites of the Great Salt Lake are, therefore, indubitably the product of lime secreting fission-algæ, and their formation is proceeding day by day. * * * According to the present stage of my researches, I am inclined to believe that at least the majority of the marine calcareous oölites with regular zonal and radial structure are of plant origin, the product of microscopically small algæ of very low rank, capable of secreting lime."

In the case of the Woolmith bed of oölite the smaller components are much compacted and their structure nearly or quite obliterated. There is a light chocolate colored, dolomitic matrix in which they show as minute whitish points and streaks. The frondescent structures are abundant, arranged parallel to the bedding and with their creamy white color give a streaked and blotched effect to the rock. Locally it has been termed "liver rock." These structures are more abundant towards the upper part of the bed and occur more sparingly in the lower portions. A laminated layer at the top furnishes a transition from the oölite to the overlying dolomite. In the case of all the oölitic beds we must assume that the material was originally calcium carbonate and that it was altered to the dolomite, through the action of magnesium salts in a concentrated solution of sea water. Favorable conditions for the formation of these beds and their conversion into dolomite were several times established. A bed somewhat similar to that of the Woolmith quarry, but which seems to be situated at a lower horizon, is seen in the Rath quarries, claim 685, South River Raisin.

B. Beds Reached by Borings.

§ 8. Deep well records.

Ten deep wells have penetrated the Monroe series of rocks to a greater or less depth. Upon Pl. V there is shown graphically the beds beneath the city of Monroe, so far as they have been revealed by the driller's record and samples. A complete series of such samples was examined by A. C. Lane and the data upon the right side of the plate determined, from which the geological identifications were made. Aside from the 210 feet of limestone previously referred to as a possible interpolation of Upper Helderberg (Corniferous), there is seen to be a series of variously colored dolomites, with or without anhydrite, down to a depth of 700 feet.* These are all referred to the series of Monroe beds the base of which is at an actual elevation of about 110 feet below sea-level. This same series of beds was penetrated to a depth of 910 feet in the Newport well, situated in the N. E. ¼, S. W. ¼, Sec. 1, Berlin, (T. 6 S., R. 9 E.) upon the estate of C. H. Buhl. The elevation of the mouth of the well, as determined by the aneroid barometer, is 585 feet. Overlying the rock is three feet of a rusty pebbly clay. The following data were determined from a study of the drillings which averaged one sample for every twenty feet. Throughout the series there occurred rusty grains which stained the neighboring fragments. Occasionally one of these showed weak magnetism but usually were unaffected by the magnet. These are believed to represent oxidized fragments of the drill.

Newport Well Record.

0 to 3 feet.	Rusty pebbly clay.
3 to 83 feet.	Drab dolomite, giving considerable muddy sediment upon being dissolved in acid. Fragments of calcite in thin crusts and considerable anhydrite.
83 to 93 feet.	Light drab dolomite, with mingled dark shaly fragments. Considerable muddy sediment. Anhydrite and sand grains present.
93 to 165 feet.	Samples not saved.
165 to 195 feet.	Drab dolomite with carbonaceous flakes, which burn with flame. Cold dilute acid acts quite energetically upon the fine drillings. Anhydrite and sand grains present.
195 to 220 feet.	Bluish-drab dolomite, drillings much compacted in vial. Anhydrite is present. Flow of fresh water secured at this level.
220 to 247 feet.	Very similar to last, but rather more anhydrite and drillings more firmly cemented together.

---

*For records of the three wells see Vol. V, Part II, pp. 69-70, and Vol. III, Part I, pp. 30 to 31, and below p. 74. The well recorded in Plate V is known as the Moore well.

247 to 305 feet.	Samples are wanting.
305 to 315 feet.	Bluish-gray dolomite, carrying anhydrite and some selenite. Much sediment left after dissolving in acid. Further flow of fresh water.
315 to 372 feet.	Bluish-gray, argillaceous dolomite. Some anhydrite present throughout.
372 to 420 feet.	Buff dolomite which leaves much yellow sediment after dissolving. The insoluble portion contains numerous rounded grains of quartz, some hornblende and some black non-magnetic grains, which are probably some form of titanic iron oxide. The rock also carries anhydrite.
420 to 435 feet.	Bluish dolomite. Drillings are coarse and very firmly compacted in vial, as though set with mortar. Lumps of anhydrite are mingled with the fragments of dolomite.
435 to 448 feet.	Quite similar to the bed 372 to 420 feet. Drillings are fine and looser as contrasted with the beds just above and just below. Much anhydrite is present.
448 to 467 feet.	Practically identical with bed 420 to 435 feet. A bluish dolomite, drillings coarse and firmly cemented in vial. Anhydrite is present in lumps.
467 to 500 feet.	Bluish, dolomitic shale. Action of cold dilute acid upon solid lumps is weak; brisk on heating for a comparatively short time leaving behind much bluish, muddy sediment. Drillings not compacted. Some anhydrite is present.
500 to 520 feet.	Bluish-drab, argillaceous dolomite. Drillings not compacted in vial. Lumps of anhydrite occur and black flakes.
520 to 560 feet.	Bluish, dolomitic shale, essentially similar to that occurring from 467 to 500 feet. Fragments of anhydrite mingled with those of the shale.
560 to 598 feet.	Blue and drab dolomite. Drillings are fine and considerably compacted in the vials. Fragments of anhydrite.
598 to 615 feet.	Drab to gray dolomite. Anhydrite and some sand grains. Lower portion of bed is more impure.

615 to 720 feet.	Drab to gray dolomite, with varying amounts of anhydrite. Some of the samples of drillings compacted in vials.
720 to 815 feet.	The five samples from this bed are all alike and more buffish than those from above bed. The rock is a dolomite also, containing seams of carbonaceous matter, fragments of anhydrite and scales of selenite. For some reason the rusty iron grains are exceedingly abundant in all the samples.
815 to 825 feet.	Drillings have a gray color and under the magnifier look much like pure anhydrite. With heated acid, however there is considerable effervescence showing the presence of the carbonates of calcium and magnesium in large percentage. The rusty grains are not quite so abundant, but are numerous.
825 to 833 feet.	The drillings from this bed are a purer white than above. In hot acid they effervesce vigorously for a short time only, leaving behind much anhydrite, which dissolves slowly and quietly.
833 to 844 feet.	Gray to dray dolomite with fragments of anhydrite and scales of selenite.
844 to 860 feet.	Samples missing.
860 to 910 feet.	Bluish gray dolomite. Drillings relatively coarse and somewhat compacted, containing bluish flakes and fragments of anhydrite.

We may assume that the Monroe beds lying between the base of the Sylvania sandstone and the Plum Creek oölite have not materially thickened in passing northward this short distance and that the thickness equals about one hundred feet. The breadth of the outcrop of this belt, measured from Brest and to the west of Newport, is about five miles, giving an approximate depth of twenty feet to the mile to these beds. Noting the position of the Monroe and Newport wells, with reference to the oölite, it will be seen that the shaly dolomite, struck in the former well at a depth of 390 feet, corresponds very closely in position to the similar rock in the Newport well reached at a depth of 467 feet, and that this is presumably the equivalent in the Ohio scale of the Tymochtee slate (§ 9). The upper belt of shaly rock in the Monroe section is also represented in the Newport series but runs into the portion of the well from which samples were not saved. The supposed interpolation of the Corniferous (Dundee) should be found in the Newport well at about 157 to 387 feet. There is, however no trace of it here, the beds seem to be dolomitic and all contain anhydrite, so far as we may judge from the nine samples.

Three deep wells have been put down within the county of which it has been impossible to secure the record or any samples of the drillings. Just before the oil and gas excitement about Toledo, a party leased land of Oliver S. Bond, Toledo, Ohio, for the purpose of putting down a test well. This was located on the S. W. ¼, S. W. ¼. Sec. 29. Bedford, one mile south of Lambertville. The well is supposed to have reached a depth of 500 feet, where it was suddenly terminated by the withdrawal of the machinery for use in the Toledo field. During the latter part of the summer and the fall of 1896 a test well was drilled in the extreme northeastern corner of Sec. 33, Berlin, (T. 5 S., R. 10 E.) upon land belonging to John Frey. The work was done under the direction of E. E. Harris, of Detroit, from whom it was impossible to secure any data. The well is supposed to have reached a depth of 1300 to 1400 feet and according to newspaper reports. penetrated a bed of rock salt at about 1200 feet. The latest and most successful well within the county was drilled in November and December, 1898, upon the land of F. C. Potter, two miles southeast of Vienna. The well is located in the N. W. ¼, N. W. ¼, Sec. 22, Erie township and its mouth is about four feet above Lake Erie level. The Trenton limestone was reached at 1555 feet and penetrated 112 feet, making the total depth of the well 1667 feet. The yield of oil and gas from this well will be given in another connection, (Chapter VIII, § 9).

Somewhat fuller data were secured concerning the Ida deep well, upon the property of Simeon Van Akin N. E. ¼, N. E. ¼, Sec. 3. This was drilled during the summer of 1893 by George M. Brown, Bowling Green, Ohio; George M. Barnes, Toledo; and Simeon Van Akin, of Ada; contractor, M. E. O'Conner, Cygnet, Ohio. The elevation of the mouth of the well is about 640 feet above mean tide level. A pipe was driven twenty-two feet to the rock when the drilling began. Ten feet of "common limerock" were found to overlie forty-five feet of Sylvania sandstone. Gray limestone (dolomite) followed to a depth of 320 feet from the surface, when a light bluish shale was struck, this constituting the "first break." The well passed through this "slate" and entered a "limestone" darker in color than the overlying beds. At about 480 feet the water "boiled as in a kettle" owing to the escape of gas. This was found to burn but had to be extinguished in order to prevent injury to the derrick. For a distance of sixty feet into the rock the flow of gas increased. At 700 feet a "light colored rock" was struck and found to be 100 feet thick. A handful of the drillings was saved by Mr. Van Akin and a sample submitted to a Chicago chemist, D. W. Chapman, who pronounced the material magnesium sulphate (epsomite) a very soluble substance, known as "epsom salts" and nowhere known to form beds of such thickness. It was stated to have been formed from the "oxydation of sulphuret of iron to a sulphate by the action of water and the decomposition of a bed of dolomite by the iron sulphate." A sample of the same substance was secured from Mr. Van Akin by the writer and it, indeed, proves to be magnesium sulphate. In its geological position in the Monroe series this bed corresponds to a one hundred foot bed of light colored dolomite carrying much anhydrite, which is shown upon Plate V, as occurring beneath Monroe at a depth of 500 to 600 feet. It is very probable that this is the equivalent of the Ida bed and that the sample of the epsomite collected just happened to come from a dry cavity in the dolomite, in which places the salt is occasionally found as an incrustation. The total depth of the well was 1200 feet when the drilling was suddenly stopped.

In the western part of the county two wells have been drilled to the Trenton limestone, each of which proved unsatisfactory so far as oil and gas are concerned. The first was drilled in 1887 in the old Christiancy quarry, upon the Macon, then owned by a Mr. R. H. Nogard. Owing to the secrecy maintained in regard to the results, it was inferred that the well had proven a success and a second one was drilled by citizens of Dundee the following summer (1888) upon the place of Alfred Wilkerson, one mile south of the village. Samples of the drillings are not available but the driller's logs are kindly furnished by Byron J. Corbin, of Dundee. They are valuable only as they enable one to infer the real nature of the beds.

Driller's record, Nogard well.*

Location, N. W. ¼, N. W. ¼, Sec. 8, T. 6 S., R. 7 E. Elevation of mouth, 660 feet.

Formations.	Thickness.	Depth of top from surface.	Elevation of top above tide.
Gray limestone	59	0	660
Buff and white limestone	100	59	601
Blue limestone	150	159	501
Buff and blue limestone	260	309	351
Oil limestone	100	569	91
Buff limestone and brown marble	600	669	– 9
Oil limestone	151	1,269	—609
Snow white marble	100	1,420	—760
Red, white and blue marble	400	1,520	—860
Shale	30	1,920	—1,260
Gray, black and brown slate	200	1,950	—1,290
Trenton limestone		2,150	—1,490

Total depth, 2150 feet.

Driller's record, Dundee well. (Sparks and Allen, Elgin, Ill.)

Location N. E. ¼, N. E. ¼, Sec. 25, T. 6 S., R. 6 E. Elevation of mouth, 680 feet.

Correlations by Lane.	Formations.	Thickness.	Depth of upper surface.	Elevation of upper surface.
Pleistocene.	Quicksand	8	0	680
	Clay	30	8	672
	Gray oil limestone	65	38	642
	Sulphur limestone	70	103	577
	Dark limestone	20	173	507
	Fine gray sandstone (Gas)	12	193	487
	Blue gray limestone	30	205	475
Waterlime	Gray sandstone	18	235	445
	Fine limestone	105	253	427
	Hard shell limestone	40	358	322
	White sandstone	7	398	282
and	Dark limestone	48	405	275
	Hard shell limestone	45	453	227
	White putty limestone	70	498	182
Salina.	White putty limestone. very hard	50	568	112
	Buff limestone	220	618	62
	Alternating blue, gray and brown limestone	315	838	—158
	Fine buff limestone	10	1,153	—473
	Gray limestone	7	1,163	—483
	Buff limestone	23	1,170	—490
	Light gray marble	15	1,193	—513
(Guelph dolomite.)	Snow white marble	135	1,208	—528
Niagara.	Dark blue marble	80	1,343	—663
	Red marble	15	1,423	—743
	Pinkish gray marble	35	1,438	—758
(Rochester shale.)	Blue slate	30	1,473	–793
	Gray limestone (Mineral water).	60	1,503	—823
Medina.	Red slate	60	1,563	—883
Hudson River.	Gray slate	100	1,623	—943
	Blue slate	110	1,723	—1,043
Utica.	Brown slate	300	1,833	—1,153
Trenton.			2,133	—1,453

---

*Mr. C. S. Nims, the driller, told Mr. Lane that there was 1,640 feet of 4 to 5 inch casing to the "slates" and from 600 to 800 feet of them, the latter including probably the Medina, Lorraine and Utica shales. These figures agree better with those of the Dundee well. A tube of samples of the latter was kept, and shows selenite, but was shaken up. The record of the Dundee well was given in the Dundee Reporter, Dec. 7 and 21, 1888, and Jan. 11 and 21, 1889.

Entered Trenton 144 feet securing oil and gas in small quantities, both of which disappeared and no more water was secured. Total depth of well 2277 feet.

§ 9. Interpretation of records.

In addition to the 200 feet which comprise the upper part of the Monroe series and which are exposed in various parts of the county, there are about 700 feet in the vicinity of Monroe which are known only through these deep well records. As stated in previous sections the thickness is less towards the Ohio line and increases northward. These beds consist of variously colored dolomites, some carrying considerable quantities of anhydrite. At 390 and 450 feet of the Monroe section the dolomite contains some shale, which is very probably the horizon of the "Tymochtee Slate," of N. H. Winchell. This was described and named in the geology of Wyandot county.* In his report of 1893,† Orton calls attention to this bed as one of the few recognizable horizons in the Ohio scale and states that it occurs below the middle of the series and probably within one hundred to two hundred feet of the base. At Monroe the bed itself has thickened from the twenty-four feet found in the typical Ohio locality and its lower layers lie from two hundred to two hundred and fifty feet from the base of the series. The shale reported in the Ida well at a depth of 320 feet is too high up for the Tymochtee and seems to correspond with those shaly beds which comprise the upper part of the Monroe section.

Beneath the Monroe beds in southeastern Michigan there lies a compact, rather homogeneous mass of dolomitic limestone known as the Niagara or Guelph. This is typically fine grained, very light colored and free from anhydrite and salt, apparently formed in the open sea before the concentration of the sea-waters had begun which characterized the succeeding age. The Monroe section shows about 360 feet of this formation, which near its middle portion becomes arenaceous. In Ohio the lowest member of the Niagara is a light colored shale, with thin calcareous bands. In the Wyandotte well‡ ten feet of "slate" are regarded by Lane as the equivalent of the Niagara (Rochester) shale. Below the Niagara lies a bed of greenish and reddish shale, about one hundred feet in thickness, to be referred to the Medina of the New York series. These colored

---

*Survey of Ohio, Vol. I. 1873, page 633.
†Survey of Ohio, Vol. VII, page 16.
‡Geol. Sur. of Mich., Vol. V, Pl. LXVI.

shales pass into the bluish Hudson River (Lorraine) calcareous shales which show a thickness in the Monroe section of 400 feet. In southern Ohio the Hudson River consists of alternating layers of blue limestone and blue shale. Northward the amount of limestone diminishes so that it is all liable to be classed as shale in well records. According to Orton it also grows darker in color and difficult to separate from the underlying Utica. Towards the Ohio line the thickness becomes less, reaching in northwestern Ohio 300 feet. The Utica consists of a mass of brown bituminous shale, becoming black towards its base. Its thickness seems to be about 160 feet beneath Monroe. Part of the 300 feet assigned to the Utica in the correlation of the Dundee well belongs to the Hudson. Finally comes the coveted Trenton, the deepest bed yet reached by the drill in this portion of the state. At Toledo the top of the formation is struck at about 812 feet below mean tide level. In the Potter well near Vienna its elevation is 978 feet below tide. In the three Monroe wells the Trenton was found to be lower toward the west or northwest. In the Moore well, third ward, the elevation is—1154 feet; in the Long well, 2d ward, it is —1149 and at the brick yard in the west part of the city it was found to be —1160. The average of these three gives —1154 feet. In the Dundee well the elevation was stated to be —1452 feet and —1490 in the Nogard well. These data give a drop in the Trenton from Toledo to Monroe of seventeen feet to the mile and from Monroe towards Dundee of about 26 feet per mile. These beds are all known in outcrop to the south, in Ohio, and northward about the shores of lakes Michigan and Huron. In southern Ohio the Trenton consists of heavy beds of true limestone with interstratifications of shale. Towards the north the shale becomes less and the rock passes into a true buff colored dolomite in which condition it enters Michigan. From the general dip of the Trenton it is apparent that Monroe county is located on the western slope of the great Cincinnati anticline.

CHAPTER IV.

QUARRIES.

A. Dundee Formation.

§ 1. Macon quarry.

This bed has long been known as the "Christiancy quarry," from the early owner, Judge I. P. Christiancy, formerly of Monroe. It is now owned by B. E. Bullock, of Toledo, Ohio. It is located in the former bed of the Macon River, from which the water has been deflected by an embankment, and extends for a distance of about thirty rods along the stream, with a main excavation of 450 by 200 feet. This is the most promising locality in the county for a high grade limestone, since the same beds are here exposed as at the now famous Sibley quarry, near Trenton. The quarry lies two miles northeast of Dundee, one-eighth mile from the Detroit and Lima Northern R. R. and three-fourths of a mile from the Ann Arbor Railroad. The nearness of the Macon interferes now with the quarrying of the deeper and heavier beds, but with an extension of the quarry northward, in which direction the stripping increases only slowly, the annoyance caused from the water would be gradually diminished. At present the water is pumped from the deeper portions of the quarry and drains slowly into the abandoned Nogard well. It thus seems likely that the deepening of the quarry will open up subterranean passages through which the quarry may be perfectly drained.

Four beds may be recognized in the quarry which may be designated as A, B, C and D in descending order. Bed A, the uppermost, consists of a rich, gray limestone from one to two feet in thickness, abounding in fossils. The limestone is relatively soft, glistens with cleavage faces of calcite and is thin bedded and more or less shattered. In the eastern portion of the quarry the top ledge of this bed has an elevation of about 660 feet above sea level. The second, or bed B, has a thickness of 4 to 4½ feet and in places is nearly or quite without a seam. In other portions of the quarry it is divided into thick beds. The rock is a compact, brownish limestone which assumes a bluish gray color on weathered surfaces. Fossils large enough to be seen with the naked eye are not as abundant as in the overlying bed and the cleavage faces are smaller. The rock gives a strong bituminous odor and drops of oil are occasionally seen in fresh specimens. With dilute hydrochloric acid a brisk effervescence is always obtained when the cold acid is applied to the solid rock. Toward the bottom the bed becomes somewhat cherty and in places there is interposed between this bed and the underlying bed C a seam of impure chert, varying in thickness from one to two inches. At the same horizon there is also to be seen in places a one inch seam of blue clay, more or less charged with sand. The main excavation of the quarry has taken place in these two beds but two deeper ones have been penetrated and their characteristics determined. Bed C has a thickness of seven to eight feet, is a soft limestone of a dark gray color, either without seam or very heavily bedded. Beneath this lies a somewhat similar eight foot bed, which the analysis shows is richer in calcium carbonate. The following table shows the chemical composition of these four beds, as determined by Mr. G. A. Kirschmeier, of Toledo.

	Bed A.	Bed B.	Bed C.	Bed D.
Calcium carbonate	90.80%	86.80%	77.60%	95.00%
Magnesium carbonate	6.87	11.60	17.41	3.86
Silica	.48	1.10	2.78	.81
Iron	.16	.12	.56	.41
Organic matter	1.69	....	1.63	....
Difference	.00	.38	.02	—.08
	100.00%	100.00%	100.00%	100.00%

Mr. K. J. Sundstrom, of Trenton, General Manager of the Sibley quarry and chemist for Church and Company, has analyzed specimens of the two upper beds with the following results:

	Bed. A.	Bed B.
Calcium carbonate	98.10 %	86.96 %
Magnesium carbonate	.63	10.08
Silica	.70	1.86
Iron oxide and alumina	....	.62
Sulphur	.055	.123
Difference	.515	.357
	100.000%	100.000%

From a careful study of the beds of the Sibley quarry it has seemed reasonably certain that the Macon beds are the equivalent of the deeper and better beds of that quarry. The analysis of the cores from the two test holes in the Sibley shows that their wonderful "9 foot bed" is from forty to fifty feet above the base of the series. The record of the Nogard well (Ch. III, § 8) shows at a depth of fifty-nine feet, a change from gray to buff limestone which probably marks the change from limestone to dolomite. If this is the correct interpretation, and there is much confirmatory evidence, bed D of the Macon quarry extends from thirty-eight to forty-six feet above the base of the Dundee formation. The actual difference in elevation between the top ledges of bed D and the "9 foot bed" is eighteen feet, this representing the amount of drop towards Trenton in the direction of the strike.

§ 2. Dundee quarry.

This consists of a rectangular excavation about 240 by 90 feet, upon the north bank of the Raisin, just back of the National Hotel in the village of Dundee. It is but a few feet from the water's edge, and as it is worked only in the late fall, was full of water at the time of each of several visits. Most of the information concerning the beds was obtained from Mr. Horace Pulver, the present owner, supplemented with a study of the blocks of stone piled about the quarry. The uppermost, or layer A, is two and one-half feet thick and consists of a rich, gray limestone, impregnated with oil and full of fossils. Fresh specimens are somewhat darker in color than those from bed A on the Macon, which it otherwise much resembles. Bed B is four and one-half feet thick and consists of a grayish brown limestone which gives a bluish effect on weathering. It shows but few fossils and is apparently identical with bed B on the Macon. The upper fifteen inches is said to be irregularly clouded and "gnarled." A third bed has been penetrated and found to be six and one-half feet thick. It is dark brown and bituminous and in the lower twelve to fifteen inches becomes cherty. Beneath this occurs a discontinuous seam of chert, carrying silicified fossils. It is of a light gray color, with brown streaks and is impregnated with black oil. It is very probable that this chert marks the same horizon as the similar seam in the Macon quarry and hence that bed B there is the equivalent of bed C in this quarry. Beneath the chert there occurs a heavily bedded five foot bluish layer, bed D, which becomes lighter colored towards its base. All the limestone in the quarry responds promptly to cold dilute acid upon the solid rock.

§ 3. Petersburg excavations.

No real quarry has been opened up in this vicinity so as to give a satisfactory rock exposure, but stone has been removed from the bank of the Raisin in ditching and also from the river bed. Mr. Jacob McCarthy, from a thirty year acquaintance with this region, was able to furnish the most complete information. In front of Spalding's flour mill, upon the river bank, just below the railroad bridge, a ledge of pure gray limestone was struck at a depth of about eight feet. A slab of this stone is now used as a horse block in front of the M. E. parsonage of the village. It is very probable that this is simply a drift mass of Dundee, similar to that described in § 3, Ch. II, as occurring upon the Stewart farm northwest of Monroe. In the river flats S. E. ¼, N. W. ¼, Sec. 4, Summerfield, farm of John Peters, ledges of limerock are said to be struck at a depth of five to six feet and it was intended to open a quarry here at one time. Upon land here, now owned by Louis Carman, a large block of Dundee limestone, eighteen to twenty inches thick, was removed while deepening a ditch. This block now lies in the barnyard of Mr. Carman's residence at the N. W. ¼, N. W. ¼, Sec. 31, T. 7 S., R. 6 E. where it is to be broken up and used as foundation stone. At the mouth of this ditch rock is struck with a probe at the depth of fifteen to twenty-four inches. Fragments have been removed here and the chips left scattered about indicate that it is a brown dolomite. According to Mr. McCarthy considerable stone has been removed from the river bed at this point and used for foundation walls in the village. Immediately below the dam the fall of water has cleared out a hole, laying bare the rock at a depth of fourteen feet below low water mark. This rock, Mr. McCarthy says, is blue-streaked limestone similar to that found in the Lulu quarry. So far as may be judged from the indications the break from the Dundee limestone to the Monroe dolomite is situated very near the village of Petersburg.

B. Monroe Beds.

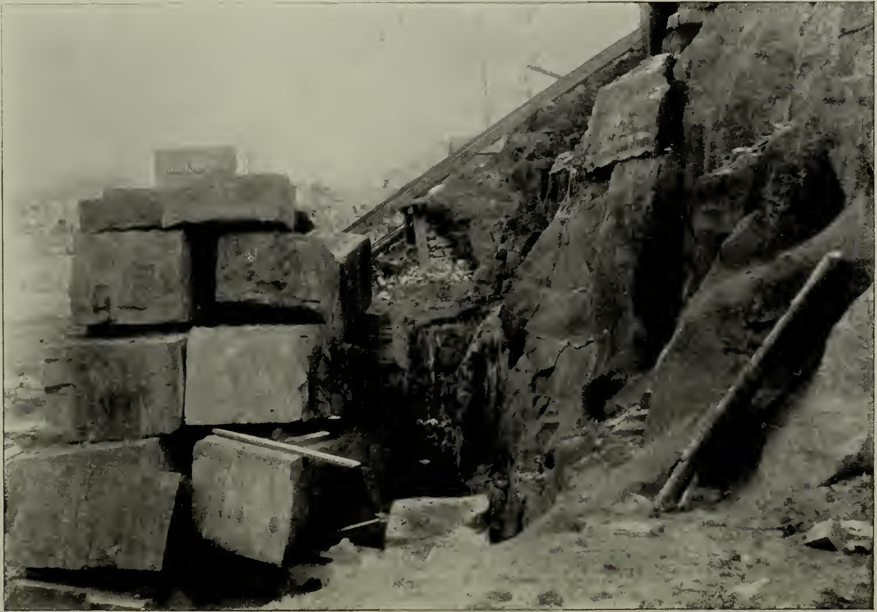
(a) Quarries Above the Sylvania Sandstone.

§ 4. Woolmith quarries.

These are located in Exeter township, about half way between Maybee and Scofield, N. E. ¼, S. E. ¼, Sec. 29. The chief one is owned by the Michigan Stone and Supply Company, headquarters in Detroit, Truman H. Newberry treasurer. During the past season it has been operated by George E. Currie, a contractor of Detroit. A short branch of the Detroit and Lima Northern enters the quarry ground and furnishes the necessary shipping facilities. A quadrilateral opening has been made, about 500 by 300 feet and to a depth of forty-five feet. A small amount of water trickles into the quarry, which collects at the southwest corner, from which it is pumped to the surface. One of the largest crushers in the state is operated in connection with the quarry, along with six gangs and one double gang of saws. The stripping consists of two to eight feet of blue boulder clay. This increases in thickness rapidly towards the east, south and west; but less rapidly to the north. Eastward just across the road, its thickness is fifteen feet; two hundred yards south it is twelve feet; while southwestward towards Maybee it is eighteen to twenty. Nine different beds, more or less distinct from one another, can be recognized and may be conveniently numbered in descending order, as was done in the previous descriptions. The direction of their dip is approximately W. 25° S. and the amount is two to three degrees. This is entirely local, the beds here being pushed upward into a knoll similar to that seen in the Sibley quarry. Bed A is a light colored, finely laminated dolomite, responding but slowly to cold dilute acid unless the rock is powdered. It is mainly of creamy white, but is blotched and streaked with dark gray to brown. Its thickness varies from two to four feet, being thinner in the eastern part of the quarry where in places it has been entirely removed by the great ice sheet, permitting the next lower bed to become glaciated. Its upper surface is smoothed, polished and striated. Where most weathered the rock becomes somewhat soft, mealy and gritty to the feel. In places it is porous and cavernous owing to the dissolving action of the surface water and sink-holes "large enough to take in a horse" were discovered when the stripping was first removed. When weathered the *Stromatopora*-like lamination becomes more apparent, and is similar to that observed in the Gibraltar and Grosse Isle quarries and in the upper part of the bed there occurs a similar stratum of gasteropod moulds and casts. Where nearest the surface the individual layers are thin, but become thicker toward the western part of the quarry where the rock assumes a bluish cast. Bed B is the three and one-half to four foot bed of dolomitic oölite previously described in § 7, Ch. III. Its lower surface is rendered very irregular by the hummocky nature of the upper surface of bed C. In conforming to these large hummocks the bed becomes laminated, a character which it does not elsewhere exhibit. Small cavities carry celestite, calcite and a little native sulphur. Bed C may be traced entirely around the walls of the quarry, varying from fourteen or fifteen inches to three feet in thickness. It is a drab to brown dolomite, in places almost as homogeneous, tough and campact as "lithographic stone," but in others it is open and cavernous the stone appearing soft and rotten. The large hummocks above referred to may be several feet in diameter, and the rock composing them consists of fine concentric laminae, convex upward. Large cavities contain celestite, calcite and sulphur and above and below the bed there occurs a thin seam of impure asphaltum. The underlying bed D is a dark brown to gray dolomite varying towards blue. It attains a thickness of five feet but may be reduced to one foot where the bed D is correspondingly increased. Its component layers are from two to eight inches thick and are, in places, plainly laminated with streaks of blue, gray or brown dolomite and delicate films of carbonaceous material. This character is more pronounced and the heaviest bedding occurs in the deepest, southwest corner of the quarry. Compared with the beds C and E this one is much more compact and free from the mineral bearing cavities, but it is more or less impregnated with oil. Locally it contains multitudes of a minute *Leperditia* and a miniature *Spirorbis*. Beneath this compact layer lies a much more open and cavernous one, bed E, from one to three feet thick, known locally as the "sulphur bed." It is a dark brown porous dolomite thoroughly impregnated with oil, giving it a strong bituminous odor and filling it with black blotches. Casts and moulds of simple corals, brachiopods and lamellibranchs are much more abundant than in the adjoining beds. Numerous cavities, more or less ellipsoidal in shape and in varying size from a fraction of an inch to two or three feet, are found throughout the bed. These cavities contain beautiful crystallizations of calcite, celestite and sulphur, intermingled in such a way as to indicate that they were simultaneously deposited from percolating water.* Upon a level with this bed there escapes into the quarry a stream of water from which sulphur is still being deposited; white, soft, and mealy looking at first but becoming

---

*Sherzer, Am. J. Sci., Vol. L, 1895, p. 246.



WOOLMITH QUARRY, SOUTH WALL, SHOWING MASSIVE BLOCKS OF SILICIOUS DOLOMITE.

yellowish upon exposure. Portions of the bed are compact and furnish building stone of a brown, bituminous character.

The five beds above described are essentially dolomitic limestones and sharply separated from the underlying beds F. G. and H, which consist of a mass of sand grains embedded in a dolomitic matrix. The uppermost, or bed F, varies in thickness from two to three feet and from its blue color it is one of the most conspicuous in the quarry. It has a gritty feel and becomes almost a sandstone in certain layers. It is permeated with vertical flexures, sub-cylindrical channels about three millimeters in diameter and several centimeters in length. These contain carbonaceous matter and oil and probably mark the position of seaweeds about which the sand and dolomitic slime accumulated. The channels are more abundant in the upper part of the bed and occur sparingly in the lower part. Near the top it becomes laminated with black, bituminous streaks. Towards the bottom the bed loses its blue color, becomes blotched with brown and merges into bed G. These blotches and streaks of chocolate brown fade out and we have a gray, highly silicious dolomite, from three to four feet thick. This passes without break into a beautiful sixteen foot bed (H) of light gray silicious dolomite, which is marketed as a "sandstone." This is so solid and free from seam that immense blocks may be cut out by means of steam chisels as shown in Plate II. When broken the rock gives a very coarse, conchoidal fracture. Occasional "glass seams" and dark streaks of grains of iron oxide somewhat disfigure the rock for building purposes. The dilute acid gives but slight action upon the solid rock, but upon the powder the acid gives brisk effervescence. Five grams of this powder give 1.37 grams of insoluble residue, or 27.4%, consisting of some alumina, with bituminous matter, but mostly of a white sand resembling that of the Sylvania bed. Examined under the microscope these grains are found to have been secondarily enlarged against the rhombohedrons of dolomite, giving them a roughened exterior and proving that the enlargement took place after the formation of the bed (see § 6, Ch. III). This series of silicious dolomites has a thickness of 21 to 23 feet in this quarry. Beneath lies bed I, a compact, even grained, gray dolomite heavily bedded. This has been penetrated fifteen feet and found to rest upon the Sylvania sandstone. Analyses of samples from the Woolmith quarry were made in 1895 by Prof. McDermott with the following results:

	4 feet down.	18 feet down.	24 feet down.
Silica	6.19	3.05	97.76
Iron oxide and alumina	.45	.31	.55
Magnesium carbonate	43.53	44.59	1.43
Calcium carbonate	50.12	52.72	1.14
Difference	—.29	—.67	—.88
	100.00	100.00	100.00

The first sample may have been derived from either bed A or B, depending upon the part of the quarry from which it was taken. The second very probably came from the bed E, while the third, representing a typical sandstone, must have been a poorly selected sample from beds F or G. The three upper beds of the Woolmith quarry are also seen in the small opening upon the adjoining property, to the south, belonging to John Hoffman. From four to six feet of clay stripping cover the rock, which has been entered ten to twelve feet.

§ 5. Raisinville quarries.

A series of six quarries occurs near the river in Raisinville township, which owing to their location and the similarity in their strata may be conveniently grouped together for description. The largest and most important of the six is owned by Robinson and Taylor, of Detroit, and is operated by Silas A. Kring for lime. It is located upon claim 516 (North River Raisin), at Grape and consists of two main excavations, one upon either side of the highway. From twelve to fifteen feet of strata are exposed, corresponding to the lower part of bed H and to bed I of the Woolmith quarry above described. The stripping is reduced in places to but a few inches of clay, charged with irregular fragments of the shattered dolomitic beds. The rock is estimated to dip 2° to 3° toward a little south of west. Upon the north side of the road the silicious dolomite forms the uppermost ledge on the west quarry wall. It is of a buffish gray color, gritty from the numerous sand grains, with numerous small irregular cavities, many of which are filled with calcite and give a spotted effect to the rock. The main quarry rock consists of a buffish gray, compact dolomite, faintly glistening with minute cleavage faces. It is thin bedded and much fissured towards the top but more heavily bedded, and more silicious toward the bottom. Nodules of impure chert occur and lenticular masses several feet long and five to six inches thick through the center. The following analysis was reported to have been made by J. D. Pennock, chemist for the Solvay Company, Detroit:

Magnesium carbonate	45.01
Calcium carbonate	51.69
Silica	3.45
Iron oxide and alumina	.20
Calcium sulphate	.43
Difference	—.78
	100.00

Just west of the quarry, upon land belonging to John Knaggs, (claim 428, North River Raisin) there is an outcrop of the same strata upon the south side of the road. A quarry was opened at this place and rock removed to a depth of twelve feet for building purposes. Not having been operated for some time the small excavation is now filled with debris and there are exposed only the protruding upper layers. Over a considerable area about this outcrop rock can be struck with a three foot probe. A quarry similar to that of Robinson and Taylor might be here developed. Beneath each the Sylvania sandstone must be expected to be reached very soon, so that neither could be extended to any depth with a yield of dolomite. The main stratum of dolomite in these two quarries, bed I of the Woolmith quarry and the bed found to overlie the Sylvania at the Toll pits, are apparently identical.

Directly south of these two quarries, upon the opposite side of the river, Fritz Rath has opened up two small quarries upon claim 685. The most northern is located some 250 paces northeast of the residence and consists of a rectangular opening, 70 by 85 feet. This was worked for lime about twenty years ago, the quality of which was reported to be good. At the time of the visit the quarry was filled with water but numerous fragments of the rock were found scattered about. These indicate that the beds are a dark brownish dolomite, streaked and finely specked with a creamy white, looking very much like a very obscure oölitic structure. Upon dissolving a flake of the rock in acid there is left behind a quantity of pure white rounded sand grains, varying considerably in size. These are secondarily enlarged against the rhombohedrons of dolomite, and oölitic granules, as in the case of the Woolmith rock previously described, giving their surfaces a very rough appearance under the low power of the microscope. The clay covering here is said to be eight to twelve feet thick. South of the Rath residence about one quarter of a mile a natural exposure occurs, at which three small linear excavations have been made for rock for building purposes, exposing five to six feet of the series. The upper bed is four feet thick and is a light to dark brown dolomitic oölite in which the structure is much obliterated. Upon dissolving small fragments in acid a considerable quantity of fine snow-white sand grains remain. These resemble those previously described, being secondarily enlarged and roughened. Occasionally one is seen with crystal facets developed or with the pyramidal termination. The rock appears to be a dolomite, enclosing sand grains and quantities of the varied oölitic structures previously described. It is associated with a gray, compact dolomite which resembles the main quarry rock upon the opposite side of the river, but shows some thin, narrow plant stems or leaves. Unless there is some local faulting here which would bring the Woolmith oölite down about thirty feet, it seems most probable that this represents a local modification of the lower layers of bed H of the latter quarry. In thickness and general appearance it resembles the Woolmith stratum but the latter upon being dissolved yields much more bituminous matter. In the well of John Nicols a core was taken out at the N. E. ¼, N. W. ¼, Sec. 26, T. 6 S., R. 7 E., to a depth of sixty-three feet. After passing through some hard pan this same silicious oölite was struck at nine feet, of which a three and a half inch core was secured. At a depth of about twenty feet a bed of white sandrock was reached which Mr. Nicols believed to have been seven to eight feet thick. Dolomite was then entered, which so far as may be judged from a single sample saved, was highly silicious.

Upon the lower portion of this same claim 685, Frederick Milhahn has opened a small quarry where the rock lies but one foot from the surface. Just across the fence to the west a second small opening has been made upon the land of Mrs. Nora Sullivan, claim 683. These lie about one and one-quarter miles southwest of the Grape quarries and have been operated ten years, mostly during the winter months, for building stone. The rock has been entered but three to four feet and is seen to be a heavily bedded, brown to gray silicious dolomite, having a rough gritty feel.

§ 6. Ida quarries.

One and one-half miles west of the village of Ida the rock strata again appear at the surface owing to local flexures. Just where the north and south quarter section line of Sec. 4 intersects the Adrian branch of the Lake Shore R. R., three quarries have been opened. The principal one has been operated for lime and building stone for many years by Nelson Davis. This is located to the south of the railroad in a field of about eight acres, one mile east of the Ann Arbor R. R. Superficial excavations have been made over a considerable portion of the field. The beds have no perceptible dip within the limits of the quarry and are drained by a small stream flowing southeastward. Mr. Davis recognizes two separate beds which he terms the first and second formations respectively. The uppermost attains a maximum thickness of seven to eight feet in the central portion of the quarry. Based upon excavations about the quarry, Mr. Davis believes that this bed gives out in each direction, from ten to fifteen rods north and east, about one-half mile west, and before it reaches Lulu, two and one-half miles to the southwest. It consists of a light gray dolomite which in places assumes a creamy white, owing to its partial or complete conversion into strontium carbonate *(strontianite)*. Near the middle of the quarry nearly a foot of the dolomite has been so altered, giving a soft, mealy rock with seams and films of the pure mineral. Some slabs are covered with a layer of slender well formed, orthorhombic prisms of this strontianite. The bedding is thin, varying from an inch, or less, to six or seven inches. Near the surface of the bed certain slabs show a remarkable amount of what may best be described as *gashing*. The rock looks as though, when it was only very slightly plastic, it had been jabbed in every direction with a thin bladed, double edged knife point. The gashes are almost always open, intersect one another irregularly and vary greatly in size, some being two-thirds of an inch long, while others can scarcely be seen without the magnifier. The cross section of each gash shows that it is thickest at the center and that it slopes gradually and symmetrically to a very thin edge. Traces of this peculiar structure are found throughout the Monroe series, from the highest rock seen at Petersburg to the lowest outcropping at Stony Point. It is not known what mineral could have crystallized in the dolomitic matrix and left these openings by its removal. One specimen from the Raisin bed shows them filled with calcite, but this may represent a secondary deposition.* In his report of 1860, Winchell refers to this as an *acicular* structure and infers that it is characteristic of gypsum. Rominger uses the term acicular also in describing the Ida rocks and calls attention to the widespread character of the phenomenon, but does not name the substance by which it may have been produced. It is to be noted that the crystals, however, were not needle shaped and only the cavities in cross-section give this appearance. In weathered specimens there are shown plainly the frondescent structures associated with the spherical granules in the beds of oölite previously described. These make up the body of the rock in places, their dim outlines showing in the solid dolomite. The oölitic granules are much obscured but are recognizable, proving that this bed is, in part at least, an oölite. In position it is the equivalent of the bed struck in the Nicol's well, above mentioned, and in the Rath quarry. The characteristic chocolate brown blotches are locally abundant. No fossils were collected from any of the strata. Rominger determined the amount of calcium carbonate in a sample to be 59% and of magnesium carbonate 39%.

Underlying this bed is the so called "second formation," which is well exposed in some of the deeper excavations of the quarry. This is a firm dolomite, dark when damp, but drying to a light gray. The surface of the bed is rough and irregular and the upper three to four inches porous and open, containing numerous moulds and casts of gasteropods, brachiopods and corals. Distinct lamination is to be seen in places. A drill core of this and the deeper beds was taken out in 1895; but the cores had been disturbed and some lost, so that the record obtained from them was unsatisfactory, except in a few cases where the depth had been penciled upon the core at the time of its removal. A silicious dolomite, streaked with blue, was found to overlie the bed of white sandrock struck in the Nicol's well. This latter appears to be six to seven feet thick, but contains much dolomitic matrix, and extends from about twenty-four to thirty feet of depth in the well. Beneath this bed lies a compact silicious dolomite, streaked and blotched with blue, which in turn, cannot be many feet above the surface of the Sylvania sandstone.

Just west of the Davis quarry there are two small excavations which have entered the "first formation" to a depth of two to three feet. The larger lies just west of the highway and north of the railroad upon the property of Michael Voight and the other to the south, upon the opposite side of the railroad, and belongs to Byron Wilcox.

---

*I am inclined to refer it to calcite. It seems to be a widespread phenomenon at about this point in the geological scale, as I have noticed it frequently in the Upper Peninsula. See also Rominger Geol. Sur. Mich., Vol. I, Part III. p. 27, and Dana's Geology, p. 247 of the first edition. L.

§ 7. Lulu quarry.

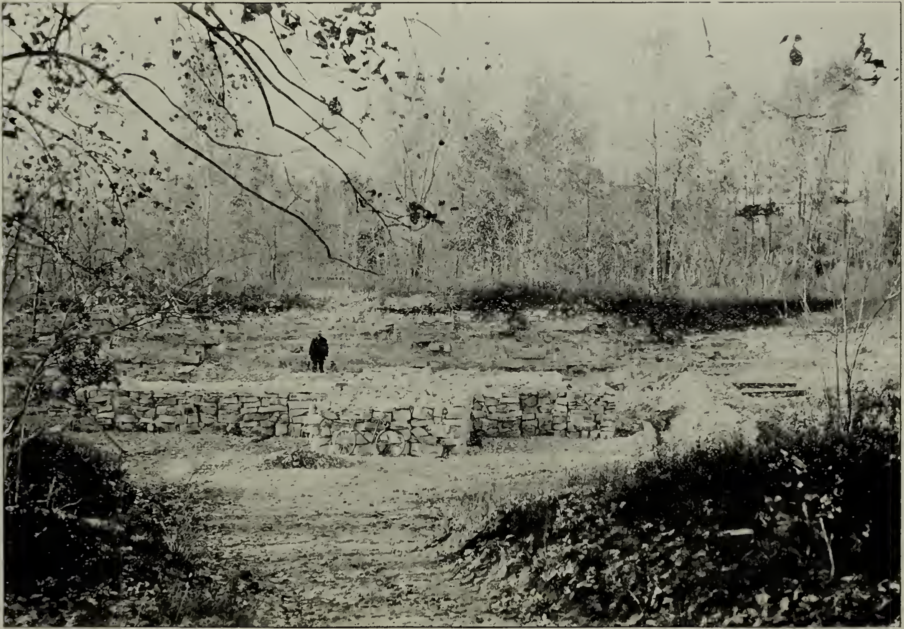
In Sec. 16, N. W. ¼, N. W. ¼, the rock rises to within three to five feet of the surface, upon land now belonging to Henry McCarthy. Rock for local building purposes was removed here fifty years ago and the main part of the quarry for many years was in possession of Henry Y. West, now of Lulu. The excavation contained too much water at the time visited to allow a satisfactory inspection of the beds, but they were seen to correspond with those penetrated by the drill in the Ida quarry. The strata have here been thrown into a fold giving a high local dip to the east and west by south. This might be a good place to test for oil. A v-shaped break extends northeast and southwest across the quarry on either side of which the strata are said to overlap "like shingles on a roof." The quarry has followed this break for nearly one hundred yards and the layers have been removed for a short distance on either side, the west wall furnishing the best exposure. An upper layer nine to ten inches thick, is a buff dolomite, highly charged with rounded sand grains, varying considerably in size. Beneath is a twelve inch layer of a less gritty, tough, light gray dolomite, succeeded by a white sandstone layer of the same thickness. These three feet represent the lower portion of the sandrock of which cores were obtained in the Davis and Nicol's wells. The main quarry rock consists of those dolomites which lie between this bed and the Sylvania proper, of which eight to nine feet have been exposed. These are compact gray dolomites, more or less mottled, streaked and blotched with rather vivid blue coloring matter. Some of the rocks much resemble in appearance, as Rominger suggests, castile soap. According to Mr. West there are two acres here over which rock could be easily quarried, lying within one quarter of a mile of the Ann Arbor R. R. An analysis of the dolomite gave Rominger the following:

Calcium carbonate	54%
Magnesium carbonate	42
Quartz sand	4

§ 8. Little Sink quarry.

A small but interesting quarry has been opened upon the eastern edge of what is known as the "Little Sink," to be later described. The excavation lies in the S. E. ¼ S. E. ¼ Sec. 2, Whiteford township upon land owned by Morris Cummins. Over an area of ten to fifteen acres the rock lies very near the surface, so that the scanty soil is practically unfit for agricultural purposes. The rock in some places is entirely bare of soil, while in others its thickness varies from one to two feet. Upon the west side of the quarry there is practically no stripping, but this reaches a thickness of one to one and one-half feet upon the eastern side. In passing southwestward from Lulu the surface of the rock is depressed, covered with a heavy belt of sand, and next reappears here at the surface in consequence of having attained an elevation above sea level of about 670 feet. The quarry is nearly equi-distant from the Ann Arbor R. R. and the Toledo-Adrian branch of the Lake Shore railroads, being about five miles from each in a direct line. In consequence, the markets are entirely local the demand being simply for building stone. The present quarry was opened about thirty-five years ago, but previously stone had been superficially quarried for building purposes and for the manufacture of lime upon a small scale. The opening is in the form of an irregular quadrilateral about 100 by 50 feet, and the strata have been penetrated from nine to ten feet. The water enters the crevices of the rocks through which it drains away except in the early spring, when the entire region is liable to be flooded.

Two fairly distinct beds may be recognized which overlie a pure white sandrock in which the grains are cemented by a dolomitic matrix. A comparison of these beds with those previously described shows that they are intermediate between the beds exposed in the Ida and Lulu quarries, being, indeed, those penetrated by the drill in the Davis quarry before the white sandrock was reached. The Lulu strata will then be exposed here by going deeper. The uppermost bed is thin-bedded and varies in thickness, within the limits of the quarry, from three to five and one-half feet. Typically it is a compact, tough, gray dolomite, showing a rather bright greenish stain in places. Towards the surface it is fissured and weathered considerably, showing a rusty iron coloration. The rock is penetrated with numerous channels which seem to be the preserved bur-



"LITTLE SINK." CUMMINS QUARRY. SHOWS ALSO SCANTY SOIL AND STUNTED FOREST GROWTH.

rows of marine annelids. Fossils are abundant at certain levels. The second bed is three and one-half feet thick and is a gray dolomite streaked horizontally with blue, as seen in the Lulu quarry. In the upper foot of this bed these blue streaks are altered to a rusty brown, suggesting that the blue coloration is due to some oxidizable compound of iron. No fossils were observed in this bed except a faint trace of a cephalopod. A few cavities occur in which are found crystallized masses of calcite and strontianite. There also occur some peculiar stylolites, in the form of sub-cylindrical plugs, in diameter ranging from one and one-half to eight inches and in length from one and one-half to seven inches. They are set vertically in the strata with their upper ends on a level with the surface of the rock. They separate quite readily from the rock in which they are embedded and show the peculiar splintery surface, which characterizes these structures. Occasionally one is seen which is well defined above but which gradually merges into the rock of the stratum and its form disappears. The film of carbonaceous matter commonly present is here represented by an iron stain, or by the blue coloring matter with which the bed is streaked. These plugs have the same composition as the surrounding rock and on being broken show no internal structure. The upper end of each is deeply concave and in every one observed there is a small handful of angular chips of dolomite loosely cemented together. The most plausible explanation seems to be that in the general disturbance of the region the rubbing of the strata over one another detached the small chips. Some of these collected in the cavities at the upper ends of the stylolitic plugs and were preserved, while those which remained between the strata were ground to powder. The structures themselves strongly suggest an organic origin but are believed to have been caused, in some unknown way, by pressure. A small sink and quarry occur upon the place of Daniel Rabideu at the S. W. ¼, N. W. ¼, Sec. 10. This lies about half way between the quarry just described and those to be described in the next paragraph. Only a small amount of stone has been removed. It is a horizontally streaked dolomite, of a dark drab color, containing some minute calcite crystallizations.

§ 9. Ottawa Lake quarries.

These are located near the head of the lake in the east central part of Sec. 7 and the west central part of Sec. 8, Whiteford township. They represent one nearly continuous irregular excavation but lie upon the adjoining properties of no less than seven different individuals. The main excavations belong to Ezra Daniels and Frank Kane and are in the S. E. $\frac{1}{4}$, N. E. $\frac{1}{4}$, Sec. 7. The rock in this region attains the highest elevation of any in the county, being about 680 feet above tide, or 107 feet above the level of Lake Erie. The dip of the beds is irregular, but high compared with that in other quarries of the county. In the Daniel's quarry it ranges from four to nine degrees and in direction is approximately W. 20° S. Owing to the elevation and channeled condition of the strata there seems to be no trouble with quarry water. Ottawa Lake station is distant two and one-half miles but the railroad itself is less than two miles from the quarry in a direct line.

Four beds may be recognized which may be conveniently referred to by letters as in preceding descriptions. The uppermost, or bed A, is a compact, gritty dolomite of a buffish brown color. Dilute acid applied directly to the cold solid rock gives but little action, but when the rock is powdered and the acid heated the action is vigorous and continues for a considerable time. There is finally left a little brownish sediment and a considerable quantity of fine sand grains, which give the same appearance under the microscope as those found in the Woolmith silicious dolomites. The surface of the bed is more or less broken and softened by water action, the dolomitic matrix being partially dissolved, leaving behind a rock relatively richer in sand. The entire stratum thickens in the direction of the dip, becoming thinner and thinner bedded toward the north and east. Bed B is a cherty layer having a thickness of twelve to eighteen inches in the Daniels quarry, but thinning rapidly northward and disappearing upon the west wall of the Kane quarry. The chert is much shattered as by earth movements and is impure, being altered in places to a soft, gray, mealy substance. Considerable clay has been deposited in the crevices, undoubtedly from surface water. The bed yields some fossils. The main quarry rock is obtained from bed C which is a compact dolomite of the same general character as that of bed A. The lower layers have a deep blue color, which in the upper part of the bed has all been altered to a buff. The same change in color has occurred lower down along seams and near the surfaces of the individual strata, so that much of the rock quarried from this bed shows only a blue core. Numerous ellipsoidal concretions occur, reaching a diameter of five to six inches, and one stylolitic plug was found, similar to those seen in the Little Sink quarry. This bed attains a thickness of nine to ten feet with two quite distinct structural breaks. Bed D forms the floor of the Daniels quarry and shows two feet in the McQuarrie quarry to the northeast, where it was burned for lime but found to yield a poor quality. It is a buff to gray compact dolomite, gritty to the feel and showing some carbonaceous films. In the latter quarry the strata are nearly horizontal, but in the Daniels quarry drop off rapidly in the direction of the dip from an open seam which extended in a northeast and southwest direction. In the quarries immediately adjoining those above mentioned the same silicious dolomite is exposed. About two hundred paces eastward a small opening was made and rock was quarried for lime to a depth of three to four feet.

At the northern end of the lake, upon a level with the water when it is full, there occurs an outcrop of a gray dolomite, S. E. ¼, S. E. ¼, Sec. 7. An old side hill lime kiln was operated here thirty-five years ago by Walter K. Hadley, now deceased. The rock was quarried only while the lake was dry. In general appearance and fossils it much resembles the upper bed in the Little Sink quarry. At the lower end of the lake a buffish brown compact dolomite outcrops in the bed of the small stream known as the Inlet, S. E. ¼, S. E. ¼, Sec. 19. On the north bank of this stream and just west of the railroad there stands the ruins of an old lime kiln, showing that rock was quarried from the Inlet and here burned. A small artificial opening, two to three feet deep, lies north of the stream and east of the highway and furnished rock also for the burning. This is a fine grained, drab dolomite smooth to the feel and much resembling bed I of the Woolmith quarry, with which it should be correlated. The silicious dolomites at the head of the lake are believed to be the equivalent of the overlying silicious beds of the Woolmith, differing chiefly in the character of the bedding.

The foregoing descriptions are believed to cover all the localities from which rock has been thus far quarried for any purpose from the Monroe series above the Sylvania. The dolomites seen at Flat Rock, Gibraltar and Grosse Isle belong to the same set, lying between the Sylvania sandstone and the Dundee formation exposed at Trenton. An analysis of material obtained by a drill from these beds in the N. E. ¼, S. W. ¼, Sec. 8, Ash township is kindly supplied by General Manager S. T. Crapo, of the Pere Marquette R. R.:

Calcium carbonate	55.03%
Magnesium carbonate	42.17
Iron oxide and alumina	.48
Silica and other insoluble residue	2.32
	100.00

(b) *Quarries Below the Sylvania Sandstone.*

§ 10. Newport quarries.

The fold in the dolomite layers which constitutes the "ridge" passing from Sylvania northeast to Stony Point, has brought the rock very near the surface in many places and a large number of small quarries have been opened upon it. Following the strike of the beds very closely, as does this fold, there is much sameness in the general appearance and composition of the rock exposed in the numerous openings. Towards the base of the Sylvania sandstone the dolomite becomes highly charged with rather coarse sand grains, as seen in the Smith quarry west of Newport, and in the rock removed from the bed of the Raisin. The deeper beds are more homogeneous and compact, of a light or dark drab color and are all true dolomites. Fossils, in the form of moulds or casts occur in many places and will be treated in the last chapter of this report. The bed of oölite which has been previously traced and described, happens to occupy the crest of the ridge for a long distance and is much in evidence for a bed of such thickness. The most northern openings in this series may be conveniently grouped as the Newport quarries. The most important of these lies in the N. E. ¼, S. E. ¼, Sec. 1, Berlin (T. 6 S., R. 9 E.) just south of the village of Newport Center, upon the west side of the Michigan Central R. R. The quarry consists of a roughly rectangular opening about 200 by 50 feet. At the time of visit it was filled with water, so that its depth and the beds represented could not be satisfactorily determined. The rock is of a dark drab color, certain layers being charged with fossils, but all the calcium carbonate has been dissolved. A small crusher was operated for a time in connection with the quarry, but work has ceased and the building and machinery have been removed. In the village of Newport Center, from the Lake Shore R. R. bridge, up Swan Creek for a distance of a quarter to a third of a mile, rock is readily reached in the stream and along the banks. Irregular openings have been made upon the places of Cartwright and Brancheau and rock removed for local building and construction work. Samples taken show that it is of the same character as that above noted. One and one-half miles west, upon the land of Mrs. Lizzie Smith, S. E. ¼, S. E. ¼, Sec. 34, of Ash township, a rectangular quarry has been opened having the approximate dimensions 100 by 80 feet. This also was full of water at the time of the visit. The hand samples taken show that the beds here are more or less silicious, of coarse, rounded sand grains embedded in a drab, dolomitic matrix. One specimen is a buffish gray grit, with dolomitic cement. These beds are the highest in the series of any exposed in the quarries that remain to be described and are from twenty to thirty feet below the base of the Sylvania sandstone.

§ 11. Frenchtown quarries.

In the southern part of this township the ridge changes its northeasterly course rather abruptly, swings around to the southeast and strikes the Lake at Stony Point and Point aux Peaux. In its course across the township it furnishes the sites for several quarries. The most northern of these is that upon claim 529 (south of Swan Creek), belonging to Henry G. Sissung. There are said to be here 160 acres of land over which the stripping will not average more than two feet. The quarry was opened at an outcrop some fifteen years ago where the stripping increases to the southwest. The rock dips southward a few degrees. The strata average eight inches in thickness and about seven feet have been penetrated in the deeper portions of the quarry. They furnish good building stone for the local market, consisting of compact gray and drab dolomite. A much larger opening lies upon the same claim to the southwest upon the place of Richard Labeau. Its dimensions at the time of visit were about 240 by 175 feet, superficially quarried. The character of the beds and of the rock resembles that of the Sissung quarry. In the bed and along the banks of Stony Creek, at Brest, a small amount of rock has been quarried for the local market. The exposures extend from the highway up stream for a third of a mile. The lower bed consists of a gray dolomite, filled with small, irregular cavities from which fossils have been removed by solution. Above this lies a bed of more compact darker dolomite, mottled with blue as in the case of the Lulu and other quarries located above the Sylvania sandstone. Still higher lies the bed of oölite previously described and best seen upon the property of Mrs. Mary Emerson. Following southwestward where Sandy Creek crosses the ridge, for a distance of three-fourths of a mile, rock can be struck with a probe and appears at frequent intervals in the bed of the stream. A small amount of the rock has been removed upon the place of Peter Suzore. It is a tough, compact rock of a grayish drab color.

The most important quarry in the eastern part of the county is the one now being operated by the Monroe Stone Company. This is located in the southern part of Frenchtown, about two miles north of the city of Monroe, claim 64, North River Raisin. It lies between the Lake Shore and Michigan Central tracks and is connected with the Pere Marquette by means of a switch, so that the shipping facilities are all that could be desired. The quarry was opened in September, 1895, since which time work has been actively pushed and an immense amount of rock crushed and marketed. The stripping averages about two and one-half feet varying but little toward the east and west. Two hundred feet to the south it equals four feet in thickness while one hundred feet north it equals three feet. The upper layer is glaciated above, as is uniformly the case in the county. For fourteen feet the rock is thin bedded, the strata varying in thickness from two inches at the top to ten inches below, and is shattered and broken so as to have no value for building purposes. It is a dark drab dolomite, of fine grain and even texture, breaking with rough conchoidal fracture and sharp edges. Thin, wavy carbonaceous films traverse the rock. Between the strata are layers of a soft putty-like clay which hardens upon exposure. These sometimes reach a thickness of two inches and represent surface material brought in by percolating waters. A good view of the bed as seen upon the west wall of the quarry is shown in Plate IV. At the base of these beds there is a thin stratum of *breccia* made up of angular fragments of a deep blue dolomite, another which is finely laminated and further, fragments of oölite, all contained in a drab, dolomitic matrix. Beneath this lies a bluish gray layer, streaked and mottled with a deeper blue coloring substance. Two large sink holes were encountered in the quarry, which at the time of examination was in the form of a semicircle, with a radius of about 130 feet. These holes were well like openings with a diameter of six to ten feet, containing at the bottom a mass of irregular fragments, cemented with crystallized calcium carbonate. The following analyses of the rock from the upper and main beds were kindly supplied by Mr. K. J. Sundstrom:

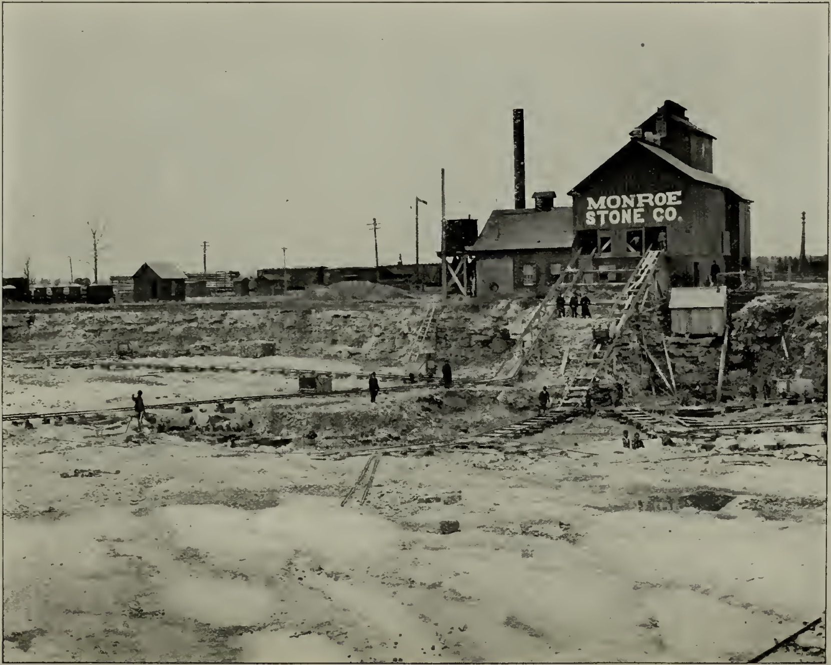
	2 feet down.	7 feet down.	10 feet down.
Calcium carbonate	54.54%	54.47%	54.94%
Magnesium carbonate	42.75	43.59	42.84
Silica	2.00	.74	1.33
Iron oxide and alumina	.70	.98	.58
Difference	.01	.22	.31
	100.00%	100.00%	100 00%

§ 12. Monroe quarries.

To the south of the city of Monroe there have been opened several quarries of more or less importance, chiefly in the immediate vicinity of Plum Creek. Some of these furnished building stone and lime in an early day to the French settlers of the region. The main excavations are upon the north side of the creek and lie upon adjoining divisions of claim 498, belonging to Alexander T. Navarre and Mrs. Mary T. Navarre. The stripping consists of a stony, yellowish brown clay, from three and one-half to five feet thick, deepening mainly towards the west. In the northeastern part of the irregular excavation two fairly well defined folds intersect one another, one bearing N. 45° E. and the other N. 60° W. From these ridges the rock dips in four directions from two to five degrees. In the A. T. Navarre quarry the dip is approximately one to two degrees toward N. 61° W. Here four beds may be recognized, the upper of which is termed the "white bed." This is a gray to creamy white dolomite, six to seven feet thick, thin bedded and fissured above, but thicker toward the base. Many loose pieces of this bed are in the clay stripping, softened upon the surface to a mealy powder. At the lower part this bed passes into a nine to ten inch stratum, which is very compact, even grained, somewhat laminated, and sparingly streaked with blue. The rock is brittle, gives sharp edges and coarse, conchoidal fracture. Owing to its higher specific gravity it is known in the quarry as the "lead bed." Beneath this lies a two foot "gray bed," made up of a fossiliferous, light drab dolomite, carrying some films of carbonaceous material. The lowest bed exposed in the quarry at the time of the visit is the so called "blue bed." This is a compact heavily bedded dolomite, inclining to drab on fresh fracture but having a decided bluish surface upon standing. Struck with a hammer the slabs give out quite a ringing sound. The individual strata have very rough upper surfaces, covered with black carbonaceous deposit. The blue color is not so marked in the portion of the quarry belonging to Mrs. Navarre and the bed not so sharply separated from the overlying one. A local deposit of brecciated material similar to that found in the sink holes of the Monroe Stone Company quarry, was observed at one place. Upon the south side of the creek the rock lies very near the surface and a linear excavation extends for a considerable distance parallel with the stream. It is here that the bed of oölite, previously described, appears. Above it is a creamy dolomite, becoming somewhat blue, while beneath is a compact, laminated bed, streaked horizontally with a rusty brown. Judging from the alteration in the mottled dolomite seen in the Little Sink quarry this bed is of the blue streaked variety. These beds underlie those above described, as well as those in the quarries north of the city.

One-half mile down stream a large quarry has been opened between the two railroad tracks by the Michigan Stone and Supply Co., the owners of the Woolmith quarry. The excavation is in the form of an irregular rectangle about 450 by 125 feet. At the time of the visit it was well filled with clear blue water so that the strata could not be examined. Toward the north side the depth is said to be thirty-two feet, penetrating a lower series of beds than are seen elsewhere in the county. The rock was used entirely for road purposes and a crusher was operated in connection with the quarry. For five years no work has been done here, owing, it is reported, to the damage done to neighboring houses by the blasting. The ledges exposed above the water are thin-bedded fissured dolomites, of a light color. In the stone pile at the crusher there are seen fragments of a compact, fossiliferous, drab dolomite; another of a bluish color and conchoidal fracture and a third blue shaly rock, friable and carrying carbonaceous seams. The former foreman says that the strata are very much disturbed in this quarry and "run every way."

During periods of low water in the Raisin, rock is quarried directly from the bed opposite the city and for a distance of three to four miles above, at frequent intervals. The lower beds thus exposed consist of gray and drab dolomites, the latter finely laminated. A view of these layers is shown in Plate VIII, but was not taken at the lowest stage of the water. Opposite claims 65 and 88 (North River Raisin) the rock is a creamy yellow dolomite, in some



MONROE STONE COMPANY, CRUSHER AND WEST WALL OF QUARRY.

layers very finely laminated. Further up the river the higher beds occur and are seen to become more silicious as the Sylvania sandstone is approached. In Willow Run, at its mouth a thin layer of sandstone occurs, which much resembles the Sylvania except for the greater coarseness of its grains. Near the top of the series there occurs a stratum of bluish gray and brown chert, somewhat brecciated and carrying obscure fossil remains.

Within a distance of a half mile south of the Plum Creek quarries four small openings have been made and rock removed for local purposes. Some two hundred paces south a small field quarry has been opened upon claim 498, belonging to Alexander T. Navarre. From three to five feet of bluish to buff dolomite are exposed. Locally the strata are laminated, in places homogeneous. The rock weathers to a soft, mealy substance of a creamy color. Numerous fragments are loose in the clay stripping, which varies in thickness from a few inches to three feet. About one hundred paces to the southwest of this quarry Dennis Navarre has a small field quarry into the same bed. Some of the rock shows the brownish mottled effect seen on Plum Creek in the beds associated with the oölite. The two other quarries are upon the same claim and are upon the banks of Tamarack Creek. The most westerly one belongs also to Dennis Navarre and is located near his residence. The opening is three to four feet deep and was filled with water at the time of the visit. The bed of oölite is here exposed and some of the overlying dolomite, which is creamy and slightly mottled. For a distance of about 300 paces down stream the rock appears in outcrop and an irregular quarry has been opened upon the property of Patrick Navarre. The rock is thin-bedded and fissured above, but the deeper layers attain a thickness of nine to ten inches. The upper strata are buff to gray and mottled with brown to a depth of four feet. Beneath this the rock is compact and of a drab color. The strata here dip 7° toward N. 16° E., both of which are abnormal.

§ 13. La Salle quarries.

No quarries of any magnitude or especial importance have yet been opened south of Plum Creek, but the rock is near the surface in many localities and the railroads are near at hand to give the necessary shipping facilities. Excepting the bed of oölite previously noted, the rock is a gray to drab dolomite, generally compact and adapted for road metal, of which the region generally stands in great need. Within the limits of La Salle township a number of minor quarries have been started, of which but little more than mention may be here made. In the bed of Otter Creek, just west of the Pere Marquette bridge, rock is now being quarried and for a distance of a mile up stream rock is accessible. Upon claim 436 (South River Raisin) Charles Heck has removed a small amount of stone from the south bank of the creek. In Sec. 20 along the south branch of Otter Creek, the surface of the rock has been reached by the stream for a considerable distance. In the N. W. ¼, N. E. ¼ of this section a quarry was opened along this branch and considerable rock removed by Jacob Clock. In the northern part of Sec. 32 and southern part of Sec. 29, along Muddy Creek, the rock is so near the surface that it had to be blasted out in deepening the stream. Some rods south in the N. W. ¼, S. E. ¼, Sec. 32, an irregular quarry, with ruins of a lime-kiln, is situated upon the land of W. W. Green. Further south in the same section, S. W. ¼ S. E. ¼, Mr. Edward Green has a small opening south of his residence. A still smaller opening was made in the N. W. ¼, S. W. ¼, upon the place of Saml. B. Cousino. Eastward in the S. W. ¼, S. W. ¼, of Sec. 33, a considerably large opening has been made upon the ridge by Eli Cousino. The quarry is an irregular one 300 by 75 feet and eight to ten feet deep, with a small test hole a short distance to the southwest. These openings are very near the north and south section line, to the east of the residence. The rock is the common type of drab dolomite, in rather thin layers.

§ 14. Bedford quarries.

Three small quarries have been opened near together and excavated to a depth of two to three feet at the center of Sec. 12, Bedford township. The largest of the three belongs to M. Butler and is in the S. W. ¼, N. E. ¼. At the time of the visit it was filled with water as is usual in the case of quarries that stand idle for a length of time. The rock samples collected show that the rock is a somewhat incoherent and not homogeneous drab dolomite. In the N. E. ¼, N. E. ¼, of this same section Thomas Blouch has opened a quarry in Bay Creek ditch, which extends some 200 yards along the stream. The stripping varies in thickness from two to four feet and the rock is a compact, drab dolomite. On the opposite side of the road, upon the place of C. L. Osgood, S. E. ¼, S. E. ¼, Sec. 1, similar rock has also been quarried. About Little Lake in Sec. 15, the rock again approaches the surface and furnishes the sites for five small irregular quarries, exposing a few feet of the beds associated with the oölitic stratum. Three of these quarries are located on adjoining land at the center of the N. W. ¼ of Sec. 15, and belong to Misses J. and N. Ferguson, Mrs. White and C. Willis. The White quarry consists of a shallow excavation extending over an area of four to five acres. The oölite previously described is here eighteen to twenty inches thick. Above this is a thin bedded, light colored dolomite and beneath is a more compact brittle variety. Lime was at one time burned here. In the Willis quarry the oölite also appears and a compact drab dolomite, streaked horizontally with bands of faint blue. The excavation is here eight to ten feet deep. In the Ferguson quarry the upper bed is much fissured and broken into angular fragments, which are recemented into a breccia. It is interesting to note that this breccia occurs at the same horizon as that seen in the quarry of the Monroe Stone Company, and the layer exposed at Stony Point (see Plate XII). Beneath the brecciated stratum there is a compact, bluish-gray dolomite. To the northwest from this group of quarries about one-quarter to one-third of a mile occur two others. One belongs to Elisha Sorter and is located in the N. E. ¼, N. E. ¼, Sec. 16, upon the ridge. This is a small triangular opening from which rock has been taken to a depth of three feet and burned into lime. The dolomite here is compact, bluish-gray and contains numerous fossil casts and moulds. To the naked eye and still better under the magnifier, it shows a very fine crystalline structure the reflections from the minute cleavage faces causing it to sparkle. Some 200 paces west a small test opening was made into the same beds and a second about 130 paces to the south, the latter showing the oölite. In the S. W. ¼, S. W. ¼, Sec. 10, upon the land of William Dunbar an irregular quarry has been opened in a meadow 100 paces east of the residence. The main rock shown here is the oölite with a small amount of overlying dolomite. One-quarter mile north similar rock has been removed from a ditch. In the N. E. ¼ of Sec. 21, a small quarry has been opened upon the road side by George Carr. Two to three feet of the bed are exposed showing it to be a thin-bedded and shattered faintly-streaked dolomite.

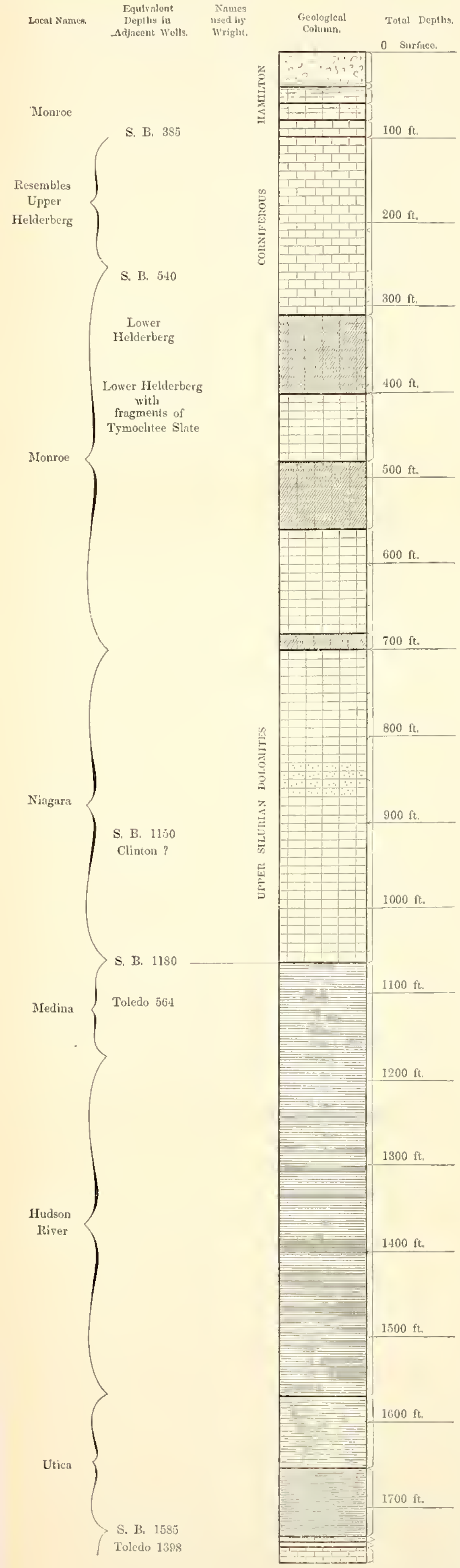
§ 15. Whiteford quarries.

There remain but two small quarries to be briefly described and these are located in the southern part of Whiteford township. Those lying above the Sylvania sandstone have been described in a previous section of this chapter. In each of these two quarries the oölitic stratum occurs in a peculiarly modified form, termed locally "bastard limestone." This is best seen in the quarry of Nelson Bush in the S. W. $\frac{1}{4}$, S. E. $\frac{1}{4}$, Sec. 25, just north of the east and west road. The rock here seems much disturbed and broken and suitable only for road work, for which it has been used. At the time of the visit a portable crusher was at work preparing stone for a road leading into the city of Toledo. The uppermost strata consist of a very compact bluish-gray dolomite which passes into the oölite, both forming a bed five to six feet thick. Beneath lies a gray compact bed which has been entered but a short distance. East a few rods considerable rock has had to be blasted from the bed of Bay Creek, in order to suitably deepen it for drainage purposes. Large blocks of the oölite and compact dolomite are found upon the bank, along the stream, for a considerable distance.

The second quarry of this group belongs to Stephen Young and is situated in the N. E. $\frac{1}{4}$, N. E. $\frac{1}{4}$, Sec. 4 (T. 9 S., R. 6 E.) about twenty-five rods northeast of the residence. The excavation is an irregular quadrilateral about fifty feet long and has a depth of five feet. Near the center of the quarry the rock strata are said to have been horizontal but about the sides appear much disturbed. The rock is the compact, modified oölite of a buff color and gritty feel, so that it is easily mistaken for a sandstone, upon superficial examination.

MONROE.

"Moore well," Monroe, Monroe Co. Elevation 585 ft. A. T.
Reported by H. Shaw Noble; samples with Geological Survey, described by A. C. Lane; in all the formations rusty magnetic grains occur occasionally. They probably represent pieces of the drill, and their frequency may be inversely proportional to the chert. Reprinted from Vol. V, Pl. XLI.



40 Bluish shale, with only a small amount of effervescent calcareous matter

60 Bluish shaly dolomite, with quite a little slowly effervescing matter.

70- 80 Bluish shaly dolomite, with quite a little slowly effervescing matter and a large clay residue.

100 Yellowish limestone, briskly effervescing.

210 Yellowish limestone, briskly effervescing.

260 S. M. Here and at 350, 500 and 650, samples of a white earthly powder of calcite and dolomite, with a trace of gypsum, (probably a chemical precipitate from underground water.)

{280 297 Water, 3000 gallons per hour.

340 S. Dolomite; effervesces slowly when in fine powder; contains much anhydrite of a dark buff color.

S. M.

370 S. Buff dolomite; effervesces slowly in splinters as though from a massive layer, with anhydrite

390 S. Buff dolomite like the sample above, mixed with greenish dolomitic shale? with gypsum

450 S. Buff dolomite like the sample above, effervescing moderately fast, with an occasional fragment of the green shale. little or no sulphate of lime.

500 S. M. S Light colored calcareous dolomite, effervescing moderately, with much anhydrite.

550 S. Light colored calcareous dolomite, effervescing slowly; in course chips, with much anhydrite.

600 Trace of gas. S. Light colored dolomite; effervesces slowly; an occasional grain of sand; no anhydrite.

650 S. M. S. Light grey dolomite; effervesces slowly; an occasional grain of sand.

700 S. Light grey dolomite; effervesces slowly, reacts for gypsum.

750 S Light yellowish dolomite; effervesces slowly; quite ferruginous; no gypsum.

800 S Bluish grey dolomite; effervesces slowly.

850 S. White arenaceous dolomite; effervesces slowly; with grains of quartz, sand and a very little magnetite.

900 S White arenaceous dolomite; effervesces slowly; with grains of quartz sand; contains a little magnetite; like the formation at 1150 of the South Bend well, Indiana.

950 Salt?

1050 Last limestone before shale. S. grey dolomite, effervescing slowly with a trace of quartz.

1110 S Greenish and reddish shales, effervescing slightly; mostly clay.

1150 S Greenish and reddish shales, effervescing slightly; mostly clay.

1250 S. Bluish grey, somewhat ferruginous shales, slightly effervescing.

1400 S. Bluish grey, somewhat ferruginous shales, slightly effervescing, with minute granules of quartz.

1570-1655 S. Green and red ferruginous shales, slightly effervescing, with a trace of magnetite.

1655-1735 Next above Trenton, S. black bituminous shale, effervescing slightly, fusing with an aromatic odor and intumescence to a blebby enamel; a little finely divided quartz.

1734-1740 First screw in Trenton. S. Buff colored dolomite; hard, with slow effervescence. At 1742 gas, odorless with white flame; considerable salt water?
1745-1750 Third screw in Trenton. S. } Both buff colored limestone.
1750-1765 4th, 5th and 6th screw in Trenton. S. }

ABBREVIATIONS.

S. is placed after points from which samples are taken.
S. M. From all the points thus marked one mixed sample was obtained.
S. M. S. Beside the mixed sample there is also an individual sample.
S. B. refers to depths in the well at South Bend, Indiana.

CHAPTER V.

PHYSICAL GEOGRAPHY.

§ 1. Climate.

The geographical position of Monroe county, its proximity to Lake Erie, its topography, and the prevailing direction of wind combine to make it one exceptionally favored so far as productive climate is concerned. It corresponds, in all essential particulars, with the noted fruit belts of western New York and northern Ohio. Lying low and flat, hemmed in on the west and northwest by morainic ridges, with the great body of water, which forms its entire eastern boundary, slowly radiating its summer heat, fall frosts are delayed sufficiently for crops to mature. Upon an average, not until October 12th does the first killing frost occur in the center of the county. During the past ten years the earliest date at which this has occurred was Sept. 21st and the latest was Oct. 30th. During the greater part of each year the wind blows from the quarter of the compass lying between south and west, as will be seen by examining Tables II and III. In consequence, the mean temperature is higher than it might otherwise be and the annual precipitation is abundant. According to statistics published in Walling's Atlas of Michigan by Dr. A. Winchell, the average annual precipitation at Monroe for eighteen years (1853 to 1870 inclusive) was 31.8 inches, with a minimum of 26.17 inches. This was distributed through the seasons as follows: spring, 8.11 inches, summer, 9.85 inches, fall, 8.27 inches, winter, 5.56 inches. During the past twelve years at Grape the precipitation has averaged about three inches less being 28.724 inches. At Toledo where approximately the same weather conditions prevail, as in the southeastern part of Monroe county, the mean annual precipitation for the past twenty-nine years is 30.68 inches, rather evenly distributed throughout the year as will appear from an inspection of Table IV. During the winter months, of course, some of this is precipitated as snow, ten inches of which are regarded as equal to one inch of rain. The average snow-fall

TABLE. II.—ANNUAL CLIMATIC DATA, GRAPE, MONROE COUNTY, MICH.—J. W. MORRIS, OBSERVER.

Year.	Temperature.					Precipitation expressed in Inches.				Frost.	Wind.
	Mean annual.	Highest.	Date.	Lowest.	Date.	Total annual.	Greatest in 24 hours.	Date.	Total snowfall.	First killing frost in fall.	Prevailing direction of wind for the year.
1888						23.99	1.60	November 11	22.5		
1889						31.50	1.35	March 31	24.3		
1890	49.4	99	June 4	0	March 6	30.41	2.92	August 21	35.1	October 21	West.
1891	50.0	96	August 9	3	February 4	25.77	1.12	November 10	27.2	October 30	West.
1892	48.4	95	July 24	—18	January 20	36.82	2.94	September 13	31.4	October 24	West.
1893	47.9	94	July 25	—10	January 14 and 15.	27.40	1.83	October 3	59.7	September 26	West.
1894	50.0	96	July 19	— 8	February 24	27.41	2.35	September 5	30.0	October 14	Southwest.
1895	47.5	94	*	—14	February 5	20.66	1.95	December 19	59.9	October 21	Southwest.
1896	49.4	97	August 9	— 8	February 17	30.73	1.87	July 26–27	33.5	September 23	Southwest.
1897	49.1	98	July 4	— 9	January 25	30.98	2.05	July 26	37.5	September 21	East.
1898	49.99	98	September 2	— 5	February 3	32.43	1.41	March 19	32.5	October 26	Southwest.
1899	49.7	98	August 11, 19	—15	February 10, 13	26.56	1.13	December 11–12	34.6	Sept. 30, Oct. 1.	Southwest to west.
Average	49.14	96.5	July 27	— 8.4	February 5	28.724	1.88	September 1	35.7	October 12	Southwest.

*June 3, July 16, August 10 and September 11.

at Toledo for the past fifteen years has been 33.6 inches, the greatest fall occurring during the winter of 1895-96, giving a total for that year of 63.7 inches. The least snow-fall during this period of years occurred during 1889-90 when there fell the surprisingly small amount of only 6.0 inches. For the past twelve years at Grape the amount is slightly in excess of the Toledo average, as would be expected. Here it has averaged 35.7 inches, with a maximum in 1895 of 59.9 inches and a minimum in 1888 of 22.5 inches. It is evident from these figures that even during winters of greatest snow-fall the bulk of the moisture received from the air is precipitated as rain. During the twelve years over which records have been kept at Grape, located near the center of the county, the maximum amount of rain-fall in twenty-four consecutive hours equaled 2.94 inches and this fell Sept. 13th, 1892. This was nearly equaled on Aug. 21st, 1890, when 2.92 inches fell.

TABLE III.—ANNUAL CLIMATIC DATA, TOLEDO, OHIO.—RECORDS OF THE U. S. WEATHER BUREAU.

Year.	Mean temperature.	Total precipitation in inches.	Total snowfall in inches.	Prevailing direction of wind.
1871	49.5	31.38	....	Southwest.
1872	48.1	27.56	....	Southwest.
1873	49.3	35.52	....	Southwest.
1874	50.1	25.83	....	South.
1875	46.4	28.03	....	Southwest.
1876	49.0	34.55	....	Southwest.
1877	50.7	35.17	....	Southwest.
1878	51.8	32.67	....	West and northeast.
1879	50.4	30.27	....	Southwest.
1880	52.0	35.72	....	Southwest.
1881	51.6	45.91	....	West.
1882	51.1	33.03	....	South.
1883	48.6	34.24	....	South and southwest.
1884	50.0	28.43	....	Southwest.
1885	47.0	33.19	41.9	Southwest.
1886	48.1	32.70	51.9	Southwest.
1887	48.9	32.01	36.2	Northeast and southwest.
1888	47.6	25.86	25.2	Southwest.
1889	49.8	21.84	18.7	Southwest.
1890	50.7	33.64	22.9	Southwest.
1891	50.3	27.12	26.7	Southwest.
1892	48.6	36.70	30.1	Northwest.
1893	48.3	23.81	44.9	Northwest.
1894	51.1	21.34	20.9	Southwest.
1895	48.2	25.31	58.6	Southwest.
1896	50.0	33.10	44.5	Southwest.
1897	49.6	30.35	31.5	West.
1898	51.0	28.10	20.9	West.
1899	50.0	27.06	28.4	Southwest.
Average	49.6	30.68	33.6	Southwest.

Of still greater importance to the agricultural interests of the county is the question of temperature, particularly its distribution through the year and the minimum reached during the winter. At

Grape for the last ten years the mean annual temperature as determined by standard instruments has averaged 49.14°, while at Toledo for the last twenty-nine years this average has been 49.6°. So far as we may judge from our data the minimum is most liable to be reached during the first week in February, but may range from the middle of January to the first week in March. The lowest temperature reached at Grape since 1890 was 18° below zero, Jan. 20th, 1892. The highest temperature recorded for this period was 99° on June 4th, 1890; unusually early in the season, the maximum averaging the last week in July. The summer isotherm of 70°, which marks the theoretical position of the sugar beet belt, cuts diagonally across the county. The distribution of the heat and moisture over the year is shown quite satisfactorily in Table IV, based upon the records taken at Toledo by the U. S. Weather Bureau.

TABLE IV.—AVERAGE MONTHLY TEMPERATURE AND PRECIPITATION, 1871 TO 1899.

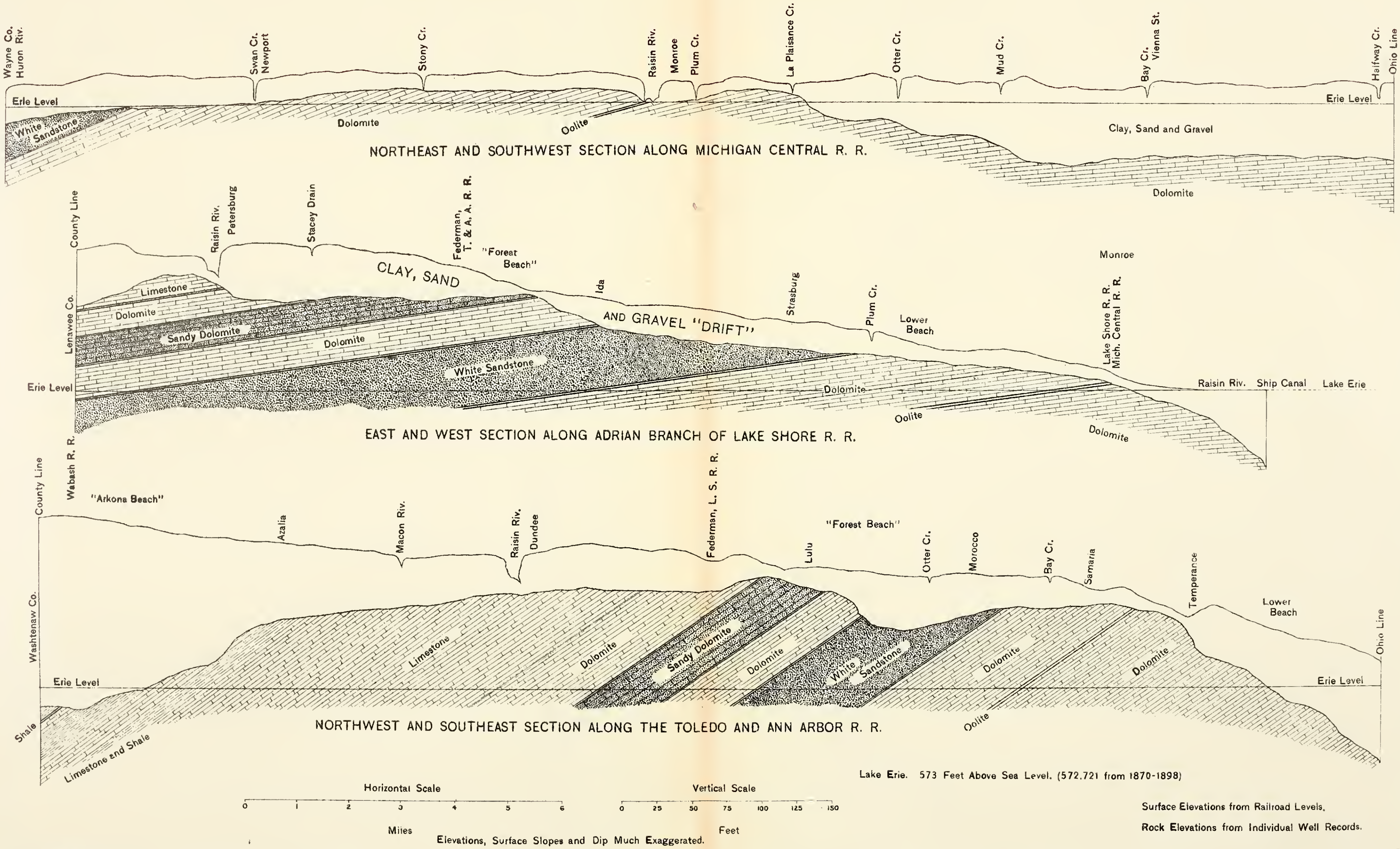
Month.	Temperature.	Percipitation.
January	25.8°	2.03
February	27.8	2.02
March	34.8	2.23
April	47.6	2.19
May	59.2	3.39
June	69.1	3.29
July	73.1	3.10
August	70.7	2.60
September	64.0	2.38
October	52.4	2.32
November	39.6	2.84
December	30.6	2.29

TABLE V.—ANNUAL CLIMATIC DATA, TOLEDO, 1860-1869.

Year.	Mean temperature.	Maximum temperature, F.	Minimum temperature, F.	Total precipitation.
1860	49.343°	94°, Aug. 6	—10°, Jan. 2	....
1861	50.368	96°, Aug. 2	— 4°, Feb. 8	36.4660 in.
1862	51.732	97°, July 6	— 2°, Feb. 15	42.9980
1863	51.069	95°, Aug. 6	6°, Feb. 3	32.6370
1864	49.987	98°, July 28	—15°, Jan. 1	37.1545
1865	49.639	94°, July 6	— 1°, Jan. 11	39.3120
1866	47.994	95°, July 16	—16°, Jan. 16	40.6878
1867	48.819	94°, July 23	— 6°, Jan. 14	31.0620
1868	47.761	100°, July 14	—10°, Feb. 3	42.9375
1869	48.512	95°, Aug. 20	3°, Feb. 28	42.2500
Average	49.554°	95.8°, July 25	—5.5°, Jan. 26	38.9087 in.

In the first volume of the Ohio Geological Survey the observations of Dr. J. B. Trembly are published in the form of two tables. These were taken at Toledo from Jan. 1st, 1861, to Dec. 31st, 1869,

GEOLOGICAL CROSS SECTIONS ACROSS MONROE COUNTY.



Lake Erie. 573 Feet Above Sea Level. (572.721 from 1870-1898)

Elevations, Surface Slopes and Dip Much Exaggerated.

Surface Elevations from Railroad Levels.

Rock Elevations from Individual Well Records.

W. H. SHERZER, Fecit

GRAND RAPIDS LITHO. CO.

and may be assumed to approximately represent the meteorological conditions that prevailed in Monroe county during this decade. Table V is compiled from these statistics and contains the more important data. It is interesting to notice that the rainfall is much in excess of that recorded from 1888 to 1899, and the lake level was higher at that time. Compare Plate V of Part II of this volume.

§ 2. General configuration of the county.

If it were not for the local mounds and irregular ridges which characterize the sand hills indicated on Plate VII, as well as the eroded stream valleys, the entire county would present the appearance of nearly unbroken horizontal plain. From the northwest corner, towards the southeast, there is an average downward slope of about seven feet to the mile, but this is imperceptible to the eye. A very gentle rise marks the position of the "stony ridge," extending from Sylvania to Stony Point, and varying in width from one-half mile to one mile. This peculiar flat effect has been produced by wave action, which cut down the natural eminences and filled in the depressions, thus grading the surface of the county until it retained barely enough slope for its own drainage. The irregularities above referred to as now to be seen, have been impressed upon the surface in a way to be presently described, after this wave action over the region affected had ceased. Upon Plate VI there is shown a series of vertical sections, across the county, along the line of the railroads, based upon the profiles of these roads and numerous well records. The upper section is along the Michigan Central, at right angles to the general direction of the surface slope, and shows the remarkably level character of the county when taken parallel with the lake shore. The lower section is along the Ann Arbor R. R. and the middle along the Adrian-Monroe branch of the Lake Shore, each cutting the direction of the slope at about 45°. The inclination of the surface is greatly exaggerated, however, by the vertical scale adopted, in order to bring out the irregularities. An inspection of these diagrams shows that the surface slopes more gently down to the broad sand belt, known as the Forest Beach, and then more rapidly to the present shore of the lake. The average grade within the limits of the county, along the Lake Shore road is 5.5 feet to the mile, and along the Ann Arbor about 4 feet.

§ 3. Elevations within the county.

Data relating to altitudes have been procured from four different sources, more or less reliable, and from these it has been possible to construct a map (Plate VII) upon which the approximate elevations are represented by a system of contour lines, drawn at intervals of ten feet above mean tide level (A. T.) at New York City. This would not have been possible in a county with broken surface features, without a much more accurate topographic survey. The contour lines must be regarded as only approximately located and are much smoother than they would appear if determined by detailed work with a spirit-level. Over the sand areas no attempt was made to represent the position of the numerous mounds and ridges of blown sand. These are frequently rapidly changed through the agency of wind and water and ordinarily their height falls within the contour interval. Upon each contour line its elevation above Lake Erie is placed in parenthesis.

(a). U. S. Survey levels. For all practical purposes the elevation of Lake Erie at the present time may be taken as 573 feet. The mean elevation for the period 1870 to 1898 is more accurately 572.721 feet. The highest level of which there is definite record was reached in 1838, when it equaled 575.2 feet; the lowest was attained in November, 1895, being then but 570.79 feet. During this sixty years the fluctuation has been 4.41 feet, enough to produce a marked effect upon the low-lying shores of the lake. Within the memory of the older residents flat-bottomed boats were loaded where now the land is under cultivation. The Board of Engineers of the Deep Waterways Commission has recommended the regulation of the lake level by the construction of weirs at the foot of the lake just below Buffalo harbor, so as to maintain a level of 574.5 feet, and insure a sufficient amount of water for navigation purposes in the fall when the traffic is greatest and the water liable to be lowest.

A geodetic station is located in the cemetery of the Monroe county Poor Farm, about four miles west of the city, the elevation of which has been confused with that of the city itself. The geodetic point is a small hole drilled in the top of a stone post set in the ground, the elevation of which at the base of the post is 43.9 feet above the mean level of Lake Erie. This mean level referred to is one that was earlier determined than that given in the above paragraph and equaled 572.86 feet. The elevation of the land then at the point indicated is 616.76 feet above tide. A second station, the elevation of which has been determined with some accuracy, lies between Dundee and Petersburg, south of the Raisin. This was also a geodetic station marked with a stone post and three reference posts. It is located in the extreme N. W. ¼, N. W. ¼, Sec. 36, Summerfield township T. 6 S., R. 6 E., on the northwest side of the diagonal road leading from Dundee to Petersburg. One reference post bears N. 76° 51′ E. and is 22.4 meters distant; a second bears S. 4° 49′ E., distant 17.55 meters. These two lie on the northwest side of the road, while the third is upon the southeast side, bears S. 18° 53′ E. and is distant from the geodetic point 34.05 meters.

The corner of Secs. 25, 26, 35 and 36 bears N. 87° 32′ W. and is 110.25 meters distant. The elevation of the ground at this point is 681 feet. A photolith copy of the Toledo topographic sheet, now being prepared by the U. S. Geological Survey, has been received during the final stage in the preparation of this report. It gives the contours of 600, 620, 640, 660, 680 and 700 feet above mean sea level for the region to the north and west of Toledo and continues them into Michigan for a distance of one and one-half to two miles. There is thus furnished an accurate and very important check upon the work based, in the main, upon railroad levels.

(b). Railroad levels. In the construction of the contour map, referred to above, reliance had to be placed mainly upon the series of railroad levels, very kindly supplied by the roads which intersect the county in so many different directions. Assuming that the profiles of these roads were approximately correct it was found that they could not be adjusted to one another with the datum plane given by the various offices; wide discrepancies appearing in the elevation of the same point. For various reasons it is best to explain here how this adjustment was made. It seemed most desirable to settle first a datum for the Lake Shore system, with its branches, with reference to lake level. The county surveyor, Mr. A. F. Winney, of Monroe, has determined that the top of the rail on the bridge at the Raisin is 19.4 feet above bed rock in the river beneath. The profiles of this branch of the road shows the rail here to have an elevation of +17 feet and that of the bed —2. The water has here become stagnant and if we assume a few inches of deposit upon the rock the figures are in agreement. Owing to the drowned condition of the mouths of all the rivers which empty into the lake, the level of the Raisin here represents approximately the mean level of the lake, and is so considered in the Michigan Central levels. The figures obtained from the Lake Shore office then are regarded as elevations above mean Erie level and, upon this supposition, are in substantial agreement with those of the Michigan Central and the Pere Marquette, referred to the same datum.

In the case of the Ann Arbor road two sets of elevations were obtained about a year apart. In one case the datum was given as the mean level of Lake Michigan (582 feet) and in the second case was stated to be unknown. At its junction with the Adrian-Monroe branch of the Lake Shore, according to the profile of the latter road, which is assumed to be practically correct, the elevation of the rail is 93.07 feet above Lake Erie level. With Lake Michigan level as a datum the profile of the Ann Arbor road gives the same point an elevation of 112.4 feet above Lake Erie. The profile of the road was assumed to be approximately correct within the limits of the county, the actual elevation of the junction with the Lake Shore, at Federman, was regarded as 93 feet above Lake Erie and the difference adjusted along the line in either direction. This brings these elevations into substantial agreement with those of the Pere Marquette, in both the southern and northern part of the county through the Detroit and Lima Northern. In the case of the latter road the datum could not be secured, but the series of actual elevations was obtained similarly by knowing the elevation of its junction with the Pere Marquette at Carleton. Upon the above basis the approximate elevation of the rail at the following stations has been computed. The elevation above mean sea level may be obtained by adding 573 feet to each. Most of them

TABLE VI.—ALTITUDES OF RAILROAD STATIONS.

(Approximate elevation of rail above Lake Erie.)

	Feet.
Azalia	102
Carleton	41
Cone	141
Dundee	95
Federman	93
Grafton	41
Ida	70
LaSalle—	
Michigan Central	15
Lake Shore	17
P. M	25
Lulu	83
Maybee	61
Milan	122
Monroe—	
Michigan Central	15
Lake Shore	16
P. M	28
Morocco	79
Newport—	
Michigan Central	18
Lake Shore	19
Ottawa Lake	119
Petersburg	105
Rea	116
Samaria	71
Scofield	52
South Rockwood—	
Michigan Central	14
Lake Shore	16
Steiner	41
Stony Creek—	
Michigan Central	21
Lake Shore	24
Strasburg	53
Temperance	46
Vienna—	
Lake Shore	13
Michigan Central	13
P. M	24

will be found to differ materially from those given in Gannett's table of railroad elevations.*

(c). Elevated beach levels. At periods when the waters of the Great Lakes stood at successively higher levels a series of beaches was impressed upon the surface of the county. These beaches thus mark actual physical contours, the approximate elevations of which are known from outside data. Their position is indicated upon Plate VII, where they furnish a check upon the accuracy of the work based upon the railroad levels. These beaches will be described in another connection and it may simply be said here that the highest marks the altitude of 170 feet above the lake, the second that of 121 feet, the third about 85 feet and the lowest about 42 feet.

(d). Aneroid levels. By means of an aneroid barometer a great many readings were taken in the course of the survey upon railroads, well curbs and rock ledges. Except where the points were near together, and but a short time elapsed between readings, no great reliance could be placed upon such determination of difference in elevation. Some of this material has been used in making up the body of this report. The barometer was found chiefly serviceable in getting the approximate height of the river terraces and banks, where these could not be measured directly. The northwestern corner of the county was found to be four feet lower than the "gravel ridge," which constitutes the 170 foot beach referred to above, and so has an elevation of 166 feet above Erie level. This beach which cuts diagonally across the N. W. $\frac{1}{4}$, Sec. 6 of Milan, is the highest strip of land within the county and functions as a minor watershed. Although a great deal of accurate levelling has been done in connection with the numerous drains, there is but little of it utilizable. The lines of levels run for but short distances and are entirely disconnected.

§ 4. Surface drainage.

A glance at the map of the county shows that the drainage is, in general, southeastward and from what has been said in regard to the surface slope it is apparent why this should be the case. Consult "Water Resources of the Lower Peninsula of Michigan." Lane, No.30 of the Water Supply and Irrigation Papers of the U. S. Geol. Survey, 1899, especially p. 62. Most of the streams make their way independently to the lake and are not united into a system, so as to form a central stream of some magnitude. The Raisin is the largest and most centrally located river but the greater part of its water it possesses upon entering the county. This has been obtained from the eastern part of Lenawee, the southwestern part of Washtenaw and the southeastern part of Jackson counties. Measured in a straight line the river is about 80 miles long but this is increased several times over, by the great amount of meandering. Owing to the very even surface slope the streams which might have become tributary to the Raisin continue their course to the lake. This is well illustrated by Plum Creek which rises within a mile of the Raisin, and for fully 18 miles flows parallel with it, entering the lake separately. At no time does it get beyond three miles from the main stream, approaches to within two-thirds of a mile for a short distance, without breaking through, and then continues lakeward for a dozen miles further. North of the river there are some minor tributaries which join it finally, only after paralleling it for a number of miles. Following the Raisin upon the south side and along many of the other streams there is more or less sand deposit outside of the main valleys. This was probably deposited as a delta upon either side of the stream as the waters of the lakes were gradually withdrawn from the land.

---

*Bull. U. S. Geol. Sur., No. 76, 1891.

Two streams worthy of the names of rivers, do enter the Raisin, however, in the southeastern part of Dundee township, the Macon and the Saline. These streams appear to have had a common bed from this point to the lake. From their point of union a broad depression extends southwestward for a number of miles into Lenawee county as shown by the surface contours. It is quite probable that this depression was occupied by a third small stream which also joined the Macon and Saline. The natural direction of the Raisin is southeastward across Lenawee county, but it takes a very abrupt turn and enters Monroe county flowing northeastward across Summerfield and Dundee townships. It seems very probable that this third stream referred to cut its way back into the watershed which separated it from the Raisin, until the latter stream was tapped and "captured." This bed furnishes a more direct route to the lake and the Raisin turned northeastward until it reached the common bed of the Macon and Saline. This bed was also appropriated, since it furnished a direct course across the two lower beaches and the Macon and Saline became tributary to the Raisin while the third stream was obliterated.

As the river swings from side to side there is cut out of the drift deposits which cover the rock, a broad valley partly filled with river silt. During times of highest flood the river leaves its channel, spreads over all the region between the outer banks, and as the velocity of its water is checked, there is deposited a layer of sediment. In the course of time there is built up a flat terrace, the height of which is determined by the height to which the water may rise at each particular part of the stream. This constitutes the flood-plain of the river. In the case of the Raisin it may be followed from near the lake, continuously up stream, across the county. Where the valley is broad and the river has a chance to spread most during flood its height is less. On the other hand where the valley is narrowest, the flood-plain terrace is highest, as is well shown at Petersburg. Here the valley, which is ordinarily from one-quarter to one-half mile in width, narrows to about 700 feet and the terrace is fully eight feet above the general level of the river. In the western part of the county the banks vary from twenty to thirty feet above the bed of the stream, are 26 feet high at Dundee and gradually diminish towards the mouth.

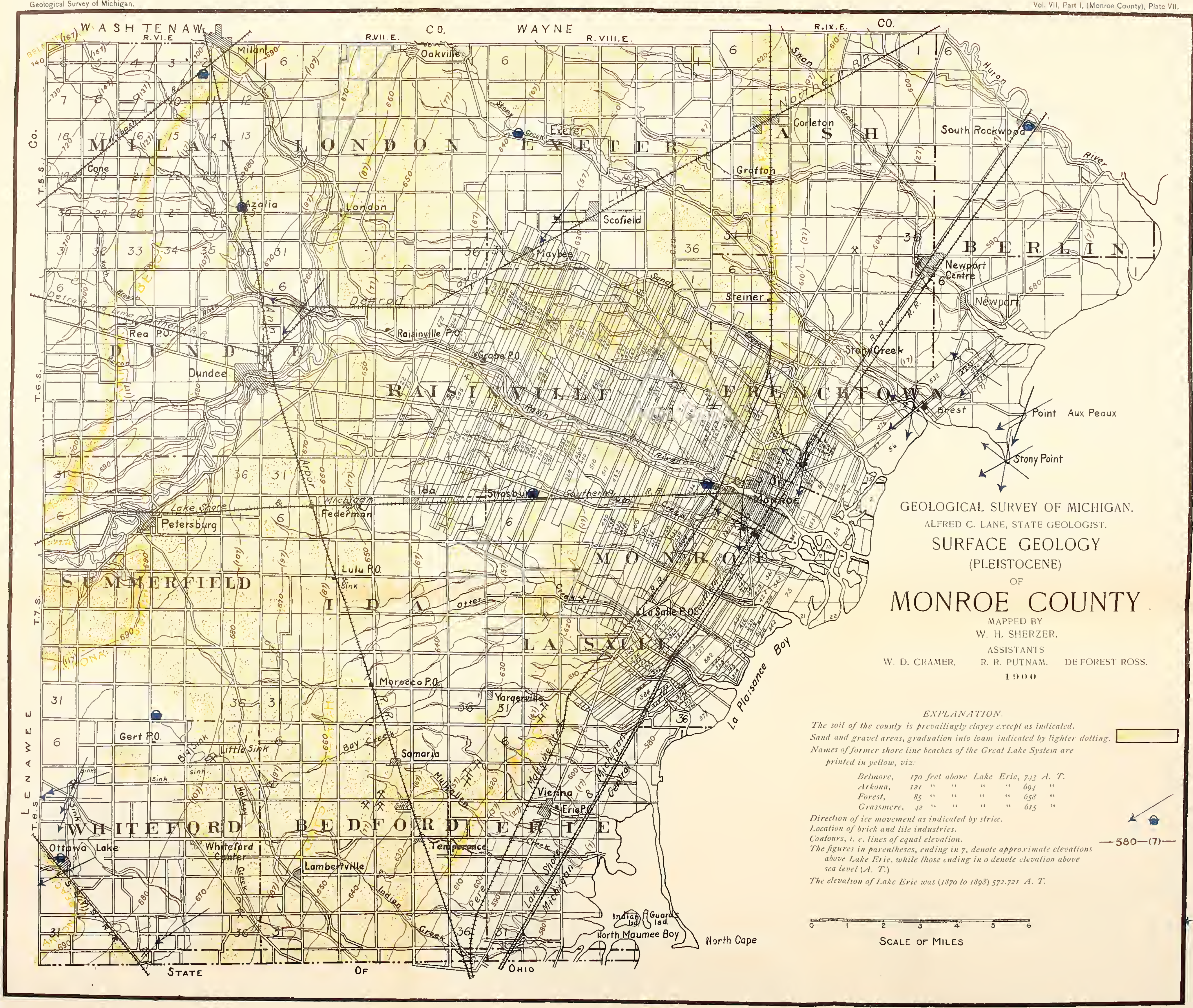
For each individual stream there seems to be a limit to the amount of wandering of which it is capable, and hence to the breadth of its valley. In the formation of the great ox-bows a neck of land is produced into which the stream cuts on opposite sides until it is completely eaten across and the channel is straightened. The abandoned portion of the bed forms a crescent shaped marsh or lagoon, numerous examples of which may be found along nearly all of the streams. The erosive action of the water is thus confined mainly to the terrace deposit of its own making, rather than to the valley banks and this is torn down and built up many times over in the history of the river. In places, however, new work is being done upon the original drift deposits and the valley correspondingly broadened until the stream is again straightened and the water withdrawn. Besides the one above mentioned, other factors contribute to the periodic straightening of the river channel. As the stream cuts laterally into its banks, owing to the deflection of the main current, it forms an ox-bow and its length is correspondingly increased. In one case noted in the Huron, near

Flat Rock, the river has meandered a mile and advanced less than one hundred feet. The actual amount of fall remains the same, while with the great increase in the length of the stream the rate of fall is much diminished. The effect of this decrease in rate is to check the velocity of the stream and to cause it to stand at a higher level at the beginning of the ox-bow referred to. The amount of this damming effect bears a direct relation to the distance which the stream has moved sidewise and tends to prevent its ever exceeding a certain amount for any particular stream. This is because the time arrives when only a slight rise in the stream will cause it to overflow across the narrow neck, and the main current will cut out a straight channel in a few hours. This action may be aided by the surface drainage, which may cut channels across this neck and reaching backward may finally tap the main stream, or form a depression through which the water may more readily find its way. This alternate meandering and straightening of the Raisin has gone on many times. Within the easy memory of the older inhabitants marked changes have occurred in the course of the stream, forest trees of respectable size now growing where there had been boating and fishing.

As has been previously stated rock occurs in the bed of the river just above Petersburg and again at Dundee. At the mouth of the Macon where the water is low, heavily bedded, glaciated limestone ledges project in the bed. For a distance of four to five miles further down the river is deep and sluggish and has a mud bottom. Just above Grape the rock again appears, and then occurs at frequent intervals to Monroe. A view of the river at Monroe is shown in Plate VIII, where the stream is from 210 to 220 feet across, being rendered shallow and broad by the layers of dolomite in its bed. Ice jams periodically form opposite the city by which the river is forced out of its banks. An unusually heavy freshet occurred this past spring (1900) from this cause and another in 1887, by which one of the passenger bridges was destroyed. The fall from the Macon to Monroe is about sixty feet, giving an average of about four feet to the mile, as measured in a straight line. Dams have been constructed at Petersburg, Dundee, Grape and above Monroe and the power of the stream utilized for milling purposes. In conjunction with Plum Creek a well defined delta has been formed between Monroe and the present shore of the lake, consisting of a

Geological Survey of Michigan.

Vol. VII, Part I, (Monroe County), Plate VII.



GEOLOGICAL SURVEY OF MICHIGAN.

ALFRED C. LANE, STATE GEOLOGIST.

SURFACE GEOLOGY
(PLEISTOCENE)
OF
MONROE COUNTY

MAPPED BY
W. H. SHERZER.

ASSISTANTS
W. D. CRAMER. R. R. PUTNAM. DE FOREST ROSS.

1900

EXPLANATION.

The soil of the county is prevailingly clayey except as indicated.

Sand and gravel areas, graduation into loam indicated by lighter dotting. ▭

Names of former shore line beaches of the Great Lake System are printed in yellow, viz:

Belmore,	*170*	*feet*	*above*	*Lake*	*Erie,*	*743*	*A. T.*
Arkona,	*121*	"	"	"	"	*694*	"
Forest,	*85*	"	"	"	"	*658*	"
Grassmere,	*42*	"	"	"	"	*615*	"

Direction of ice movement as indicated by striæ. ↙

Location of brick and tile industries. ●

Contours, i. e. lines of equal elevation. —580—(7)—

The figures in parentheses, ending in 7, denote approximate elevations above Lake Erie, while those ending in 0 denote elevation above sea level (A. T.)

The elevation of Lake Erie was (1870 to 1898) 572.721 A. T.

0 1 2 3 4 5 6

SCALE OF MILES

RAISIN RIVER AT MONROE.

low, flat marsh but little elevated above lake level, across which the river reaches the lake by several mouths. While Michigan was still a territory a canal was constructed by the general government through which more direct communication with the lake was established. Work was begun in 1835 upon this canal and the next year the city itself constructed the "city canal" cutting off the ox-bow of claim 653, by which this part of the river was rendered navigable for the lake craft of those days.

The Macon and the Saline rivers, with their branches, drain the northwestern part of the county, the southern part of Washtenaw and the northeastern portion of Lenawee. They are simply the Raisin in miniature, each showing the broad valley, the elevated flood-plain over which they pursue their winding courses. The banks are about twenty-five feet high where they join the Raisin, but gradually diminish to less than half this height.

The Huron forms the northern boundary of Berlin township, but receives no tributaries of any size from the county. It has about the same length as the Raisin and carries nearly the same amount of water. It rises in the western part of Oakland county, flows southwest across the southeastern part of Livingston, between great morainic ridges and through a chain of lakes, taking then a winding southeasterly course across Washtenaw and Wayne and entering the lake just below the mouth of the Detroit river. Rock is encountered in the bed of the stream only at Flat Rock, where it has been quarried to a small extent. The banks here are from fifteen to sixteen feet high and about sixty rods apart with a flood-plain terrace of river silt which varies in height from five to six feet. The stream itself is about ninety feet across and flows with a swift current. From Flat Rock to South Rockwood the river forms numerous characteristic meanders, similar to those above described for the Raisin. At the latter place the valley banks are eighteen feet above the general water level and about 125 rods apart. The same terrace appears as at Flat Rock, sloping upward from the low water channel to the sides of the valley. The stream maintains about the same size throughout this portion of its course to the lake. The banks are gradually reduced in size until in Sec. 23, of Berlin, they are but two feet high and the flood-plain merges into the broad, flat delta. The stream current has here been lost, although two miles from its mouth, and there is simply an ebb and flow from the lake. A strong easterly wind is said to raise the level of the water two feet. The depth of the stream is ten to twelve feet and toward the mouth is reported as in places twenty-five feet. The U. S. Coast Chart shows a depth of ten to sixteen feet. Such a depth in this portion of the stream, where there is practically no current calls for special explanation (Chapter VI, § 13). Between the Huron and the Raisin, Swan Creek, Stony Creek and Sandy Creek enter the lake directly, each with relatively broad valleys and flood-plain terraces. As has been previously pointed out rock is struck for a short distance in the bed of each. South of the Raisin we have an essentially similar set of streams, Plum, Otter, Muddy, Bay and Halfway Creeks being the principal ones. These drain mainly the region that lies east of the Forest Beach, but in the case of the latter stream the surface drainage of Whiteford to the west is brought to the lake. This cuts through the beach one and one-half miles south of Lambertville, being assisted by considerable dredging and blasting. The presence of the Arkona and Forest beaches has considerably interfered with the natural drainage of Whiteford and the southern half of Summerfield townships and has necessitated the construction of extensive artificial drains.

§ 5. Underground drainage.

In the region of obstructed drainage just referred to, nature has in part obviated the difficulty by sending the surplus water to the lake under the beach, instead of over it. Sink holes and subterranean rock channels have been produced by the solution of the dolomite, so that farms are sometimes drained into old wells. In deepening wells which enter the rock it sometimes happens that the entire quantity of water is lost by opening communication with one of these underground channels. It is reported that sometimes running water may be heard by placing the ear to the ground. In the southern part of Sec. 2, of Whiteford, there occur two large depressions, known respectively as the "Big Sink" and "Little Sink." The latter is the site of Cummins' quarry described in Chapter IV, § 15 and shown on Plate III. The "Big Sink" is a large depression, fifteen to eighteen feet deep, one-half mile long and about one-quarter broad. A ditch from the northwest drains into this and in the spring the depression fills to overflowing and becomes confluent with "Little Sink," forming a veritable lake as

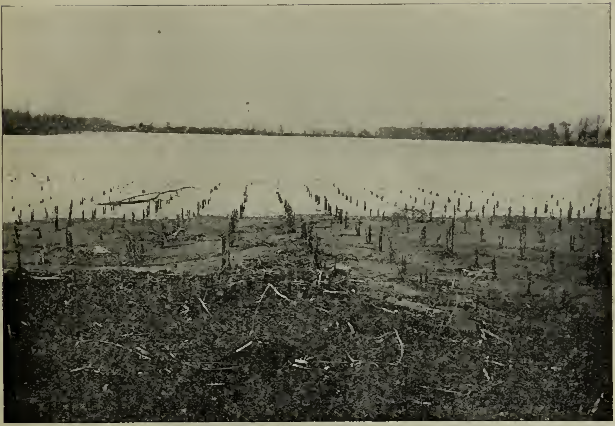


Fig. 2. The "Big Sink" doing service as a lake, March 26, 1898.

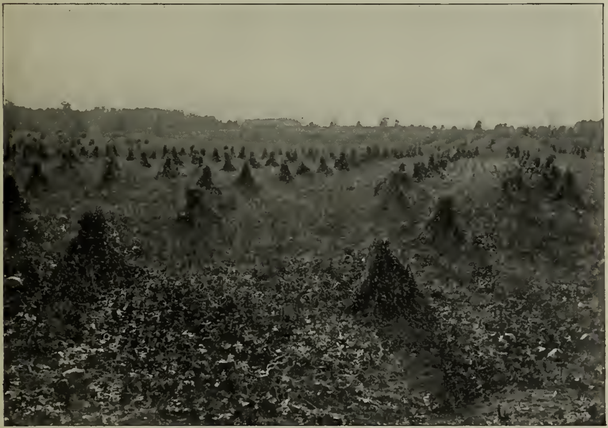
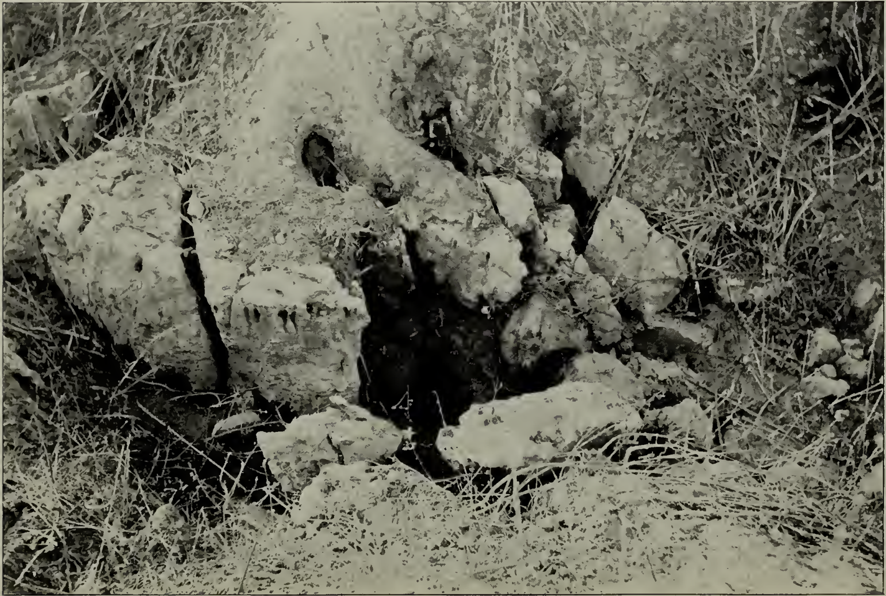


Fig. 3. The "Big Sink" under cultivation, October 15, 1898.

shown in Fig. 2. Each season it becomes stocked with fish from Lake Erie, by means of Halfway Creek, and carp weighing ten to fifteen pounds are said to be caught. In the bottom of the bed there is a small ravine in which occurs the opening shown in Plate IX. Through this the water finally escapes, sometimes very rapidly and with whirlpool effect. It is possible that an ice plug may be formed during the winter and as long as this remains intact the sink retains its water. Whatever the obstruction may be, it is always disposed of in time for the cultivation of the land and Fig. 3 shows the sink in corn. Figs. 2 and 3 were taken from about the same point, one in March and the other in October.

Southwest of these two sinks occurs a much larger one known as Ottawa Lake, lying mainly in Secs. 17, 18, 19 and 20 of Whiteford townships. This has a length of more than two miles and exceeds one-half mile in its greatest breadth, although it is narrow throughout the greater part of its extent. Each season this fills up and becomes stocked with bass, perch, carp and pike as in the above instance. By midfall this lake has practically disappeared, partly by evaporation but mainly through openings into the rock beneath. Plate X shows the bed of the lake, taken from the head looking south, when all the water has gone except the small pool in the foreground. Fish are said to be caught in large numbers as the water subsides, while those left behind to die render the air offensive for some distance. Mr. Edward Montgomery, a local well driller, informed the writer that near the foot of the lake he had seen an opening "as large as a room" leading into the rock and that he had entered it twelve to fourteen feet, but that he could see some distance further and that it contained much mud with fish, turtles and snakes. Search was made last season for this opening but all that was found was a bowl shaped depression in the mud fifteen to sixteen feet in diameter and five feet deep containing about a peck of young cat fish. During the past summer the bed of the outlet has been lowered by the county so that the level of the full lake will be reduced four feet, by which means many acres of marsh land on the south and east will be reclaimed. In the northern part of Sec. 15, Bedford township, there is a small body of water upon the "ridge," known as Little Lake. At the time of Rominger's survey of this region (1873 to 1876) this was dry and showed conspicuous rock crevices in its bed. It has not been dry for a number of years and is not now regarded by local residents as a sink. It seems prob-



ROCK OPENING THROUGH WHICH THE WATER OF THE "BIG SINK" ESCAPES.

able that the subterranean exits have become temporarily clogged and that they may again become functional upon being cleared. A somewhat similar case has occurred just south of the Lulu quarry in Sec. 16, of Ida township, where there is a depression covering five acres and about nine feet deep. This has filled each spring with water which has had to slowly evaporate. In 1896 it appears to have found an outlet, or to have opened a former one, since it was filled several times and each time emptied itself in three days. Just south of the Big Sink, in the N. W. ¼, Sec. 11, Whiteford, there is situated a sink which has become inoperative. Upon the place of Daniel Rabideu there are two small sinks in the S. W. ¼, N. W. ¼, Sec. 10 of Whiteford. In Sec. 8, N. E. ¼, N. W. ¼, there are minor sinks and sink holes, into one of which a man and horse are said to have broken through.

It is very probable that there exists throughout this region a series of underground galleries and chambers, but probably of no great dimensions. The openings are not known to show air currents, which would probably be the case if they communicated with extensive caverns. These subterranean channels seem to extend below the level of the lake and hence must have been cut when the land stood at a higher level. The water which enters these sinks supplies the great springs, which are found to the east along the lake shore. Some of it also very probably reappears in the artesian wells of the region and some of it may reach the lake directly, without coming to the surface.

There is evidence that these underground waters are inhabited by a special fauna similar to that found in caverns. Sometime in the 70's there were pumped from a well in the N. W. ¼, N. W. ¼, Sec. 32, of Summerfield township, three small fish which are said to have showed no trace of eyes. The well was eighty to ninety feet deep and stands upon land now belonging to J. Cosgroy. The fish were seen swimming in a pail by Mr. Ezra Lockwood, who gives the length of the largest as about one and one-half inches, dark brown in color, slender in form, "shaped like a mullet" but with much enlarged paired fins and the dorsal fin extending to the tail. A similar find was reported from Utica, north of Detroit, in Macomb county, some two years ago. Two larger fish were obtained from a well, neither of which according to the owner, showed any trace of eyes. Very unfortunately a cat made a meal of them before they could be secured by the writer. Similar discoveries may be expected in the future and it is to be hoped that the material will fall into friendly hands.

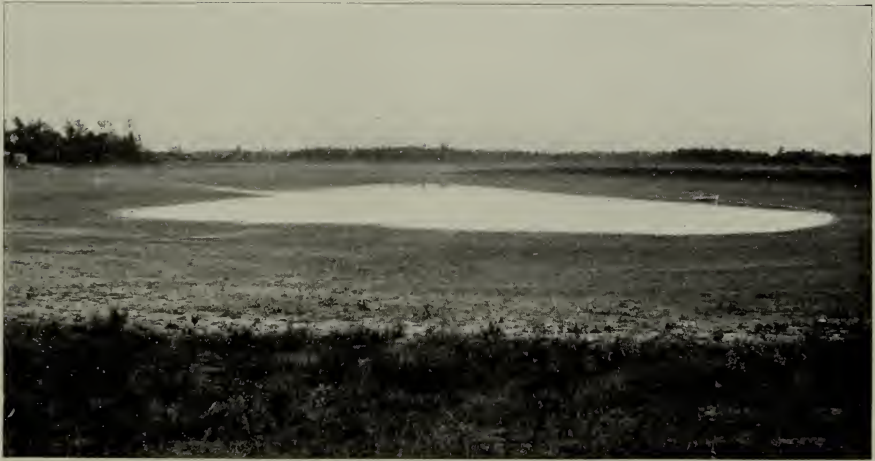
§ 6. Diagonal features.

In 1873 Dr. Alexander Winchell read a paper before the American Association for the Advancement of Science entitled, "The Diagonal System of the Physical Features of Michigan."* Attention was here called to the frequency with which the directions, intermediate between the cardinal points, enter into the physical features of our southern peninsula, and Monroe county might have been selected as a type locality. The far reaching influence of geological forces is well shown in tracing to its cause this diagonal system. The reader will recall the frequency with which the terms northeast, northwest, southeast and southwest have appeared in this report, it being almost impossible to point out a single natural feature in which this diagonal character is not apparent to a greater or less extent. The southeasterly slope causes the streams to take this general direction, the only exceptions being the Raisin, the south branch of the Macon and Halfway Creek. When these streams are not flowing southeast they are, however, flowing northeast. The present Lake Erie shore, the ancient beaches, the sand and clay belts, the outcrops of rock, the belts of artesian water and gas, all have a northeast and southwest direction. The lines joining places of equal elevation, of equal temperature, of equal rainfall and even the prevailing direction of the wind, are diagonal in the county. In consequence of the above facts the distribution of the natural flora and fauna partakes of the same character.

In the days of early French occupancy each claimant of government land was allowed any amount, up to 640 acres, for the surveying of which he was willing to pay. With no system of roads yet established the streams were the highways and each farm must have its water front. The claims were laid out at approximately right angles to the Raisin, Stony, Plaisance and Otter Creeks and what they lacked in width they made up in length, as is apparent from an inspection of the map. For mutual protection, social intercourse, water and fish, the houses were located near the streams and faced them. When the settler went to or from his work, after

---

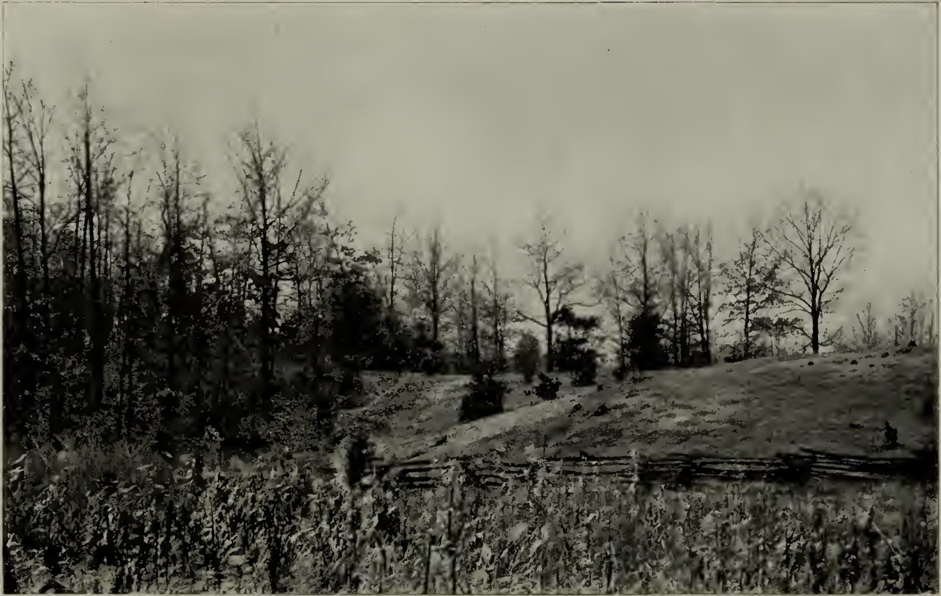
*American Journal of Science, 3d series, Vol. VI, page 36. See also "Michigan," extracted from Walling's Atlas, page 32.



BED OF OTTAWA LAKE (SINK), LOOKING SOUTH FROM HEAD, OCT. 15, 1898.

game, to the traders or to visit his neighbor, he moved, in general, parallel with, or at right angles to the stream. The activities of the home itself were similarly directed largely by the southeasterly course of the rivers and creeks. Later when roads were established they were laid out between the claims, or so as to cut directly across them at certain distances back from the river front and in the eastern and central parts of the county many of these diagonal roads still remain. As the settling of the country progressed the gravel and sand ridges of the beaches were utilized for roads. The old territorial road from Pontiac to Adrian, laid out in 1832, occupies the crest of the Belmore Beach for many miles. The farmers select these higher ridges as sites for their dwellings, because of their accessibility, better drainage and the ease with which water can be secured. For the same reason school houses, churches and cemeteries are frequently similarly located. For over a hundred years a large proportion of the residents of the county have moved, eaten, slept, worshipped and now lie buried upon the bias. When the farmer's son began business for himself he desired the same conditions to which he had become accustomed on the homestead, and these he found by migrating either northeastward or to the southwest. The topography has determined the position of the larger lakes and rivers of southeastern Michigan. These have, in turn, determined the sites of our larger cities, and between the cities run the railroads, which with but one minor exception cut the county diagonally. Along the lines of these roads have sprung up nearly all the villages of the county.

So long ago that the time cannot be expressed in years certain internal forces of the earth disturbed the originally horizontal beds of shale, limestone, dolomite and sandstone. These were tilted so that they dipped to the northwest in this region and their outcropping edges were thus given a northeast and southwest direction. The different degrees of hardness of these beds caused them to weather unevenly and subjected them to unequal degrees of aqueous erosion, so that broad valleys were cut out having the same direction as the beds themselves. To a greater or less extent the preglacial topography determined the direction of local movement of the great ice sheet and hence the direction of maximum ice gouging. The direction of the advance of the ice disposed the deposits of till, moraines, and boulders as we find them and gave to the county its present topography. This topography determined the direction of drainage, the boundaries of the series of lakes resulting from the melting of the ice and the direction of their shore lines. From the above mentioned remote cause an endless chain of causes and effects has been permanently impressed upon the county and all its inhabitants. But the forces by which the rock beds were originally disturbed represent a single link in this chain which reaches backward as well as forward. We have no means of knowing, at this remote day, what factors determined the direction of the operation of these potent forces. Could these but be identified and traced to their origin we should better understand the remark of some farseeing scholar, that if a single grain of sand on the seashore occupied the position of its neighbor, the history of the earth would have been different.



SAND RIDGE OF BEACH, WEST OF ERIE; SHOWING TYPICAL GROWTH OF OAK AND EVERGREENS.

CHAPTER VI.

THE GLACIAL EPOCH IN SOUTHEASTERN MICHIGAN.

A. Rock Surface Topography.

§ 1. Introduction.

No satisfactory knowledge of the peculiar topography, the nature and distribution of the soils of the county, can be had except through an understanding of the recent geological history of the region. Between the formation of the strata which have been described and the series of events about to be presented in this chapter, a very long period intervened. During this time the land had arisen from its long immersion in the sea and was probably not again submerged for any great length of time. It was acted upon by the meteorological and chemical agencies which operate to produce soil, the removal of which by erosion gradually brought the rock surface to a lower level. Broad, shallow valleys were cut across the county in a general northeasterly direction, which with their low, narrow divides characterize an aged river system. It is quite probable that tongues of ice moved along these valleys at times and somewhat modified their form, although their general direction does not coincide with that of the ice movement. The topography of the rock surface is shown by the contours given upon Plate I, each drawn to connect points where the rock surface is at equal elevation above mean sea level. The data for these contours were obtained by subtracting from the actual elevation of the surface, the thickness of the drift covering, so that there was a double chance of error in determining the result at any particular point. The contours must then be regarded only as approximately located, simply the best that could be done under the circumstances. The highest rock in the county extends northward through the western half of Whiteford township into Summerfield, ranging from 660 to 682 feet A. T., the latter elevation being reached at the head of Ottawa Lake. The maximum rock relief, within the limits of the county, is about two hundred feet. An inspection of the contours shows that there are three fairly well defined valleys within the limits of the county, which may conveniently be referred to by the names of the geological formations out of which they have been carved.

§ 2. Traverse valley.

This strikes northeastward across Milan township, approximately along the line of the Wabash railroad, having been cut out of the softer beds of the Traverse group. It is limited on the northwest by a narrow divide of harder rock (the Tully limestone?) which extends northeastward through sections 18, 7, 8, 9, 4, 3 and 2. This low ridge divides the Traverse valley from another which has been formed in the St. Clair shale and the two unite in the southeastern part of Washtenaw county. The stream which occupies the St. Clair was apparently tributary to that which flowed through the Traverse valley. This latter valley extended from the divide above located as far as Azalia and varied in breadth from about six miles in southwestern Milan to three to four in the northeastern part. Within the township the elevation of the central part drops from 610 to 549 feet, giving an average fall of about nine feet to the mile towards the northeast. The stream seems to have passed directly beneath the village of Milan about twenty-four feet below the present level of Lake Erie, or thirty-three feet lower than that of Lake Huron. The valley itself here was about sixty feet deep so far as we may judge from the present rock topography. Plate VI shows a section of this valley along the line of the Ann Arbor road. From well records collected in Wayne county this stream appears to have continued northeastward across Washtenaw, into Wayne and on towards Detroit, where its elevation is not far from 470 feet A. T., or about 100 feet below the level of Lake Erie.

§ 3. Dundee valley.

This is a broad, shallow trough, confined mostly to the richer and softer beds of the Dundee formation. It seems to head in the higher rocks in the northern part of Ida township, cutting across the upper Monroe beds and entering the Dundee at Raisinville. It then follows the strike of the softer beds into Wayne county, there cuts across the upper Dundee beds and opens into the main Traverse valley, showing that its stream was tributary. Within Monroe county the central part of the valley falls from 643 to 580 feet, or an average fall of four to five feet to the mile. At only one place does the stream channel itself appear to have been struck in well boring. In Sec. 18 of Exeter township, the rock averages 50 to 55 feet from the surface, but G. W. Palmer, (N. W. ¼, N. W. ¼) went 72.5 feet without reaching rock and ended in gravel. This stream probably left the county from Sec. 3 of Exeter at a somewhat higher level than did the Traverse to the west.

§ 4. Sylvania valley.

A narrow and still better defined valley followed the Sylvania sandstone throughout almost its entire course, owing to the uncompacted nature of this bed and the ease with which it could be eroded. The valley appears to have been formed by the union of two short ones, the first of which followed eastward the town line between Whiteford and Summerfield and the second came in from the northwest and joined the former in the southwestern part of Ida. The contours show how faithfully the strike of the bed was followed turning eastward with it in Ash and Berlin and cutting across Brownstown, of Wayne county. The breadth of the valley was roughly limited by the resisting dolomite beds on either side of the sandstone outcrop. In the southwestern part of Summerfield the valley has an elevation at its center of about 660 feet and drops 100 feet in reaching South Rockwood, an average of about three feet to the mile. The actual depth of the stream channel itself is unknown. One mile east of South Rockwood, in about the center of the valley (Sec. 10, T. 5 S., R. 10 E), Mr. J. M. Morrison has a well in which the depth to rock is eighty feet, while a short distance east, across the road, the rock is within twelve to fourteen feet of the surface. The lower section on Pl. VI gives a cross-section of this valley, at the outcrop of the bed marked "white sandstone." A small portion of the valley is also shown in the same bed at the left of the section along the Michigan Central road. The stream which occupied this valley emptied to the east, or southeast, very probably into the ancient "Erigan River," which is believed to have occupied the deeper portions of the bed of Lake Erie and the lower part of the Detroit River. The other preglacial or interglacial streams located appear to have continued northeastward and probably formed part of the ancient system which occupied the present site of Lake Huron.

§ 5. Erie trough.

Upon the southeastern side of the rock fold which has been previously described as "stony ridge," the elevation of which slopes from 663 feet A. T. to 575 feet A. T. at Lake Erie, the surface drops very rapidly towards the lake. The dip of the beds, upon the other hand, is towards the northwest, in the opposite direction. The steepest descent is in the western part of Erie township, where there is a drop of seventy feet within a distance of one and one-half miles. A flat shelf with a maximum breadth of two miles, then extends northeastward across the township, mostly west of the railroads and parallel with them. For the next mile to the southeast a further descent of forty feet occurs, bringing the actual elevation down to about 490 feet A. T., or 83 feet below the mean level of the lake. This rock topography is well shown at the right of each of the sections on Pl. VI, previously referred to. Northeastward this trough extends past Monroe and between here and Stony Point turns to the eastward and continues an unknown distance beneath the lake. Judging from the character of the beds affected, the shape and position of the trough, it seems probable that this is due to the gouging action of the great "Erie lobe" of ice.

B. The Ice Invasion.

§ 6. The early ice sheets.

The glacial history of the region covered by this report would be very unsatisfactory if read from this area alone. Data from widely distant localities are required in order to prepare even the most general account of this remarkable episode known as the Glacial Epoch. Two lines of evidence from within the county have been adduced to show that the land at one time stood at a higher altitude, at least, with reference to the present level of the great lakes. These evidences, it will be remembered, are the deep subterranean channels and the deeply buried river valleys. Supplemented with further evidence from other localities it is known that the land was considerably more elevated than at present and particularly so toward the north. This elevation combined with a possible change in the position of the earth with reference to the sun, the shifting of the great ocean currents or the withdrawal of a certain amount of carbon dioxide gas from the atmosphere, produced arctic conditions over the Dominion of Canada and northern United States.

A very heavy precipitation of snow over the region lying to the east and south of Hudson Bay, more falling each winter than could be melted away during the following summer, produced a great body of snow, which by its own weight and surface melting was compacted into ice, thousands of feet thick. It must have been just such a body of ice as now completely mantles Greenland and the Antarctic continent. On account of the peculiar quasi-plastic properties of ice and the elevation of the sheet, the ice moved slowly outward from the center as its production there continued.

As the ice moved to the south and west at a rate probably not greater than a quarter of a mile yearly, the frosty breath of this unwelcome visitor was finally felt about the northeastern boundary of our native state. Invading the lake region it slowly made its way southwestward, grinding and scouring the rocks, tearing loose and transporting great fragments, and annihilating every vestige of plant and animal life. The soil which had been accumulating for ages was scooped from the rocks and either pushed ahead of the ice or washed out from beneath by running water. We have no means of judging how long this great ice sheet tarried over this region, but it is known to have also crossed Ohio, Indiana, and Illinois, and to have entered Kentucky, before its progress was arrested. The ice front stood at its southern limit long enough to permit the accumulation of a great belt of debris, consisting of clay, sand, gravel, and boulders forming the line of hills known as the terminal moraine. During this stage of halt the backward melting of the ice just equaled the amount of its forward movement, so that the front was approximately stationary, and the materials undergoing transportation were indiscriminately heaped at its base. Climatic changes occurred and the rate of melting exceeded the forward movement of the ice itself, causing the ice front to slowly retreat northward. Practically nothing is known in this region of the details of this retreat; where or how often the ice front again became temporarily stationary and formed minor moraines, in what condition the drainage was left or where the water accumulated to form the great lakes of this stage. Beneath the ice sheet there had been formed the great "ground moraine," the rock grist of this great ice mill consisting typically of unstratified blue clay, charged with sand, pebbles and boulders, more or less bruised. The melting of the ice took place not only from the front but also from the upper surface and upon its complete disappearance the debris which it still contained was deposited over the surface of the clay. A forest growth of hardy trees sprang up and a dark soil bed was formed of varying thickness. Where conditions were favorable peat and marl beds and deposits of bog iron ore were formed. This first ice invasion was due to what has been termed by Leverett the Illinoian ice sheet, owing to its development in that state. A second sheet known as the Iowan is believed to have also crossed the state in the same general direction and to have restored arctic conditions. Data are not at hand for determining whether this second sheet was a simple extension of the first after a long interglacial period or whether it was developed anew as had been the first.

§ 7. The Wisconsin ice sheet.

In the same region east of Hudson Bay, over the Labrador peninsula a third great sheet of ice slowly mustered its strength and moved south and west. This was in consequence of a return to the unfavorable climatic conditions which had given rise to the first sheet. How long a time intervened we have no means of accurately judging, neither do we know how far northward the Iowan sheet had retreated. The time was sufficient to permit of the formations noted above, to allow the till to become leached of its soluble ingredients to a considerable depth, and oxidized into the reddish brown clay to which the term "ferretto" has been applied. The devastation wrought by the earlier sheets, from which our region had largely recovered, was repeated. The till covering of the bed rocks, with the superficial deposits, was in large part swept away, and the rock again heavily glaciated. The grooves and scratches produced by the Illinoian and Iowan sheets were in a large measure obliterated, and a new set substituted. From this further grinding of the rocks and the rearrangement of the materials of the former bed, a second sheet of till was formed. This differs from the earlier in being less compacted, less altered in color and of a generally fresher appearance. It is not impossible that some of the so called "hard-pan," which frequently occurs in the wells of the county, is to be referred to the deposits of the earlier ice sheets. But little trace could be obtained of a soil, or peat layer, separating the beds of till. Newspaper rumors, for several years back, have furnished some evidence of the occurrence of a layer of "coal'" embedded in the drift of the southern part of Wayne county. In Sec. 34, S. E. ¼, S. W. ¼, of Huron township, Timothy Hanrahan dug a thirty foot well to the rock passing through a ten inch layer of what he called coal. Six miles south, in Ash township of Monroe county, Sec. 30, S. E. ¼, S. E. ¼, Mathias Waldecker put down a well, thirty-four feet to rock. Just over the rock he found mixed with clay, fragments of "coal" which would burn. In Bedford township of Monroe county, N. W. ¼, N. E. ¼, Sec. 2, John Van Wormer has a well ninety feet in depth in which the rock was struck at seventy-five feet. Six inch seams of a coaly substance were penetrated. The exact nature of this so called coal remains unknown but it is suggestive of compacted peat. The comparatively few wells in which this substance was reported, as well as of the dark soil bed which was probably formed on the surface of the earlier till, may be accounted for by considering the energy with which the last ice sheet operated in this region. The looser surface materials would be very liable to be destroyed, while the compact hardpan would more frequently remain undisturbed.

This Wisconsin ice sheet did not quite reach the Ohio River, so that between its terminal moraine and that of the Illinoian the oldest bed of till was undisturbed by ice agency. Its final retreat was marked by periods of halt and short advance, of a more or less rhythmic character as pointed out by Taylor.*

Between Cincinnati and Mackinac this investigator counts fifteen terminal moraines produced by this behavior of the ice sheet. The position and form of these moraines, when traced in either direction, gives the exact position and form of the ice front at these successive stages. Great streams of water, due to the friction of the ice upon its bed and the surface melting, made their way through and beneath the ice. These streams rounded and assorted the smaller rock fragments within reach and produced great quantities of sand and gravel. Some of this material was deposited in the tunnels and cavities about the margin of the ice, forming loosely stratified knolls and ridges known as kames and eskers. Much of it was washed out from beneath the ice and spread over the till froming a gravel plain upon the opposite side of the moraine from the ice. Where this material was brought to the ice front by a single stream, whose velocity was checked as soon as it emerged from the ice, a fan-shaped, delta-like deposit was formed. None of these glacial deposits occur within the limits of Monroe county, but good examples of all of them may be found in Lenawee and Washtenaw counties adjoining.

---

*Moraines of Recession and their significance in Glacial Theory. Journ. of Geol., Vol. 5, No. 5, 1897, p. 421.

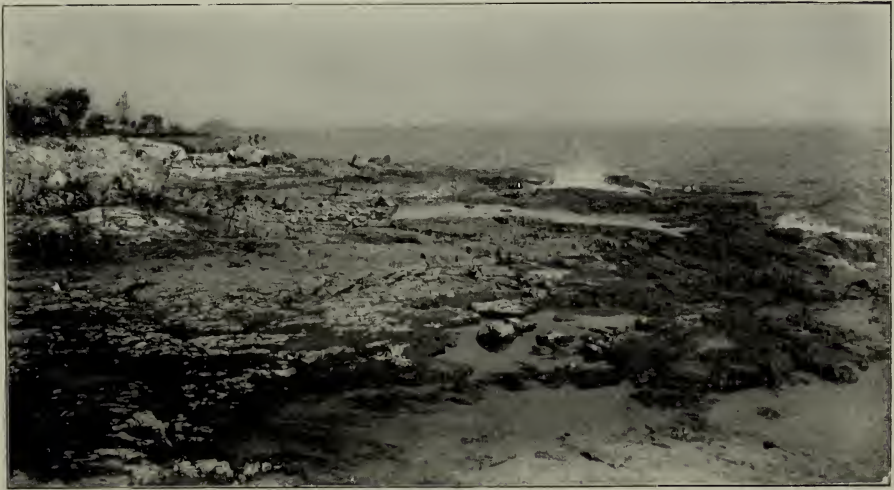
§ 8. Rock scorings.

As early as 1839 Bela Hubbard published the bearings of well defined scratches which he observed upon the rock surface at Point aux Peaux and at Brest.* These were due he then thought to "the attrition of hard bodies moving in a strong current." At the former place he determined their direction to be ("N. 60° E.") S. 60° W., and at Brest ("N. 50° E.") S. 50° W., and N. 65° W. Some twenty years later Winchell found the rock at Stony Point well exposed and "covered with a set of striæ running in perfectly parallel lines N. 60° W."† Crossing this set he found two parallel grooves, bearing N. 60° E. to S. 60° W., which were 4 ft. 6½ inches apart, 1⅝ inches deep, 2 inches wide and 25 feet long, much resembling wagon tracks in a yielding substance. The Ohio Geological Survey has at times published similar data in regard to the scorings observed in northern Ohio and the islands in the western part of Lake Erie. The first of these were collected by Gilbert and threw light upon the general direction of ice movement in southeastern Michigan.‡

In Lucas county, which adjoins Monroe county upon the south, the observations were made at four points. The mean of five observations at Sylvania gave S. 50° W.; near Holland one reading gave S. 55° W., four observations at Monclova averaged S. 62° W. and one reading at Whitehouse, the furthest south, equaled S. 50° W. Upon West Sister Island the general direction is S. 80° W., with a comparatively weak set crossing them due south. The effect of the ice upon the limestone where chert nodules protude is to produce the "knob and trail" phenomenon. The hard rock protects a ridge of limestone upon the lee side, while that in front of the nodule and along the sides is planed off and, in certain cases, grooved. This is convincing evidence of the direction of the ice movement, and as observed upon this island and at Monclova, proved that the movement was westward, rather than eastward. Upon South Bass Island the striæ run S. 80° W., with a second series S. 15° W. At Sandusky the direction is S. 80° W., at Ballville S. 65° W., and at Genoa S. 65° W. Vol. VI of the same Survey, in 1888 (page 754), devotes a paragraph to the glacial markings of Kelley's Island and the local deflection of the ice by prominent joints. The general direction of the striæ is given as S. 23° W., which striæ upon the

---

*2d Annual Report of the State Geologist, p. 113.
†Report of 1860. p. 127.
‡Ohio Geol. Sur., Vol. I, 1873, p. 538.



ICE POLISHED AND BRECCIATED OUTCROPS AT STONY POINT, LOOKING NORTHEAST.

eastern end of the island are found to be crossed by a later set extending S. 76° to 80° W.

In Wayne county, to the north of Monroe, an examination was made of the glacial striæ about the Sibley quarry. At the time of the first examination a few were found bearing S. 64° W. and these seemed to be the oldest. A recent inspection of the rock now stripped failed to show any of this series. Upon three sides of the quarry, and particularly the eastern, the rocks were heavily grooved by an ice sheet which moved about S. 28° W. Some of these grooves are from one to two feet deep, but mostly only a few inches. It is only in these grooves that these striæ are preserved. Outside they have been replaced by a newer set, the mean of 21 observations giving a bearing of N. 27° W. and a range of from N. 19° to 38° W. The evidence that the sheet moved northwestward, instead of southeastward as has been previously reported and believed, is very conclusively shown at the Sibley quarry. "Chatter marks" occur with their convexities directed toward the southeast, "disruptive gouges" are formed with their concavities in the same direction. Where the ice crossed a groove previously formed, it was not yielding enough to settle into it completely, so that the eastern side of the groove was but slightly striated while the opposite side was more or less affected, being rounded and irregularly scratched. Projecting knobs of limestone show the most bruising upon the eastern, or southeastern faces and but little upon the opposite, or lee faces. But the most conclusive evidence is furnished by one bed of limestone which contains irregular masses of chert. This bed shows the trails of limestone, extending northwestward from these harder masses, with a very decided frontal and two lateral grooves, surrounding each nodule. These phenomena have all been described and figured by Chamberlain in his paper on "The Rock-Scorings of the Great Ice Invasions," published in 1888.*

Within the limits of Monroe county there are a number of places where the glacial striæ may be observed and a few localities where they may be very satisfactorily studied. Although many irregular and more or less distinct striæ may be observed, still, so far as direction is concerned, the principal ones seem to fall into three groups which may be correlated with those observed at Trenton. These are not all equally well represented at each locality and it is not always true that the newer set predominates over the older, the latter at times having been protected apparently by clay from the work of the later sheet. The principal information relating to these Monroe county scorings, as collected by the writer, is given in the accompanying table and shown graphically upon Plate VII by means of arrows. The striæ observed by Hubbard and Winchell at Point aux Peaux, Stony Point and Brest running S. 50-60° W. "N. 50-60 E." correspond in direction with the oldest observed at Trenton, S. 64° W., and are believed to have been formed at the same time. The next oldest set has a more southerly course and was formed during an energetic stage of the ice sheet. The heaviest grooving was observed at Trenton where the direction of movement was S. 28° W. In the heavy grooves on Kelley's Island the direction of movement was S. 23° W., as given above by Orton, so that these grooves and striæ are apparently to be correlated. Between these points at numerous places striæ are found which should be referred to this same stage of glaciation. Upon the islands at the western end of Lake Erie, in the eastern part of Monroe county and at Trenton, the freshest striæ have a westerly course ranging from a few degrees south of west to 52 to 71° north of west. These were produced by the central and northern portions of the Erie lobe of the Wisconsin sheet and indicate simply that the ice moved out at right angles to its front wall, as located by the moraines. It would be natural to refer the two earlier sets of striæ to the Illinoian and Iowan sheets respectively but we have no warrant for so doing. It is true that when the next oldest set was formed the ice was much more vigorous in its action but this is only what would be expected of the Wisconsin sheet when it was first advancing across the region, or had attained its extreme southern limits. In the last stages of its retreat it was able simply to smooth, polish and striate the rock surface but not to form heavy grooves. The direction of movement of the same sheet would also be expected to differ greatly over the same area at different stages of the ice development. Quite generally, however, there is a noticeable difference in the relative degree of freshness of the striæ, the older set having preceptibly aged. In the case of the newer series there is sometimes a question in one's mind as to whether a given short scratch was produced by the ice, or by the tool with which the stripping of clay was removed. The doubt rarely arises with regard to the older set, its striæ being duller, less sharply cut and slightly weathered. In some instances, however, it seems impossible to detect such differences between the older and newer series, where they both presumably have been well protected by clay. Near Brest there is a knob of dolomite, which appears at the side of the road just south of Stony Creek. The bearings of delicate scratches were taken here sixty years ago and still appear fresh in the case of the later series. Upon the lee side of the knob the older set was protected from the last ice sheet and although plainly grooved the striæ are well nigh obliterated. This would seem to indicate that a considerable period of time elapsed between the making of the two sets, during which time the ordinary destructive agencies were at work upon the oldest. In the western part of the county the correlation of the striæ is rendered uncertain on account of the relative age which it seems necessary to assign to the two series observed at several localities. The rock in the bed of the

---

*Seventh Annual Rep. of the Director U. S. Geol. Sur., pp. 147-248.

TABLE VII.—GLACIAL STRIÆ IN MONROE COUNTY.

Locality.	Relative age.	Relative abundance.	True bearings of striæ.	Mean.
Sissung quarry	Newer	Most	N. 58° W.. N. 55° W.. N. 56° W.. N. 59° W., N. 59° W	N. 57° W.
	Older	Fewest	S. 37° W.. S. 41.5° W.. S. 31.5° W	S. 37° W.
Point aux Peaux	Newer	Fewest	Not present or quite obliterated	
	Older	Most	S. 20° W., S. 17° W., S. 19.5° W., S. 28.5° W.. S. 18.5° W..	S. 21° W.
Stony Point	Newer	Fewest	N. 51° W., N. 44° W.. N. 51° W.. N. 79° W.. N. 54° W.. N. 46° W.	N. 54° W.
	Older	Most	S. 8° W., S. 6° W., S. 9° W.. S. 8° W., S. 8° W.. S. 20° W	S. 10° W.
Brest	Newer	Most	N. 57° W., N. 58° W.. N. 59° W., N. 53.5° W.. N. 59° W	N. 57° W.
	Older	Fewest	S. 10° W.. S. 7° W.. S. 8° W.. S. 11° W.. S. 9° W	S. 9° W.
Monroe stone quarry	Newer	Most	N. 54° W., N. 52° W., N. 46° W.. N. 42.5° W.. N. 47.5° W	N. 48° W.
	Older	Fewest	S. 12.5° W.. S. 10.5° W.. S. 14.5° W., S. 10° W.. S. 13.5° W	S. 12° W.
Plum Creek	Newer	Most	N. 62° W., N. 60° W.. N 61° W.	N. 61° W.
	Older	Fewest	S. 7° W.. S. 5° W.. S. 6 W	S. 6° W.
Head of Ottawa Lake	Newer	Fewest	S. 22° W., S. 22° W., S. 19° W.	S. 21° W.
	Older	Most	S. 81° W., S. 91° W.. S. 78° W., S. 107° W	S. 89° W.
Ottawa Lake quarries	Newer	Fewest	S. 24.5° W.. S. 25.5° W	S. 25° W.
	Older	Most	S. 70° W., S. 70° W., S. 69° W., S. 70° W	S. 70° W.
Macon river bed	Newer	Most	S. 38° W.. S. 39.5° W.. S. 38° W.. S. 38° W . S. 35° W	S. 38° W.
	Older	Fewest	N. 73.5° W.. N. 76° W.. N. 73° W	N. 74° W.
Woolmith quarry			S. 41° W.. S. 36° W.. S. 26° W.. S. 26° W.. S. 47° W	S. 35° W.
Inlet Ottawa Lake, Sec. 19			S. 65 5° W	S. 65° W.
Halfway Creek, Sec. 35			S. 56° W.. S. 59° W.. S. 55° W., S. 55° W.	S. 56° W.

Macon and the Raisin at its mouth is heavily glaciated. The main direction is S. 38° W., but a few heavy scratches, apparently older, run N. 74° W. From their direction alone there should be no hesitation in referring the latter to the newer series observed to the east. At the Ottawa Lake quarries the older set runs S. 70° W. and the newer S. 25° W., while one-half mile south at the limited rock exposure at the head of the lake, the older set lies in a shallow groove, with its striæ S. 89° W. and the newer set S. 21° W. These striæ could be very satisfactorily correlated, with those in the eastern part of the county providing their age was reversed. It would seem that those having the westerly course must correspond with those made by the Erie lobe, in which case it is a problem to know how to dispose of the later series ranging from S. 19° to 39.5° W. Further observations might furnish a satisfactory explanation, but as it now appears it seems necessary to assume a local ice movement subsequent to that described as the latest in the eastern part of the county.

C. Lacustrine Stages.

§ 9. Introduction.

For some reason, possibly on account of the great weight of the ice sheet, a marked subsidence of the earth's crust occurred over the region thus covered. This change, combined with others affecting the position of the earth with reference to the sun, or perhaps an increase in the amount of carbon dioxide in the atmosphere, restored the equable climate which this region had enjoyed previous to the great catastrophe and led to the disappearance of the ice sheet. The melting of such a body of ice, together with the normal precipitation, would furnish enormous quantities of water for the greatly disturbed river systems to take care of. The sub-glacial streams, contracted by narrow walls, would leave the ice with great velocity and carrying much sediment. Upon spreading out in the depressed and partly filled river channels, leading from the ice front, the velocity would be greatly checked and much sand and gravel deposited. This epoch was short when compared with the preceding and corresponds more or less with the Champlain epoch of the east. A reëlevation of the land followed the disappearance of the ice sheet, the streams were given greater fall, and hence greater velocity, and began clearing out their obstructed channels, forming a series of terraces at successive levels. While this was the course of events in the east a very different program was carried out in southeastern Michigan and northwestern Ohio.

§ 10. Lake Maumee.

(a). Van Wert stage. As the ice began its retreat northeastward down the Maumee valley from Ft. Wayne, Indiana, lower and lower land was successively exposed. This depression filled with water as the ice receded, and a lake of correspondingly greater proportions was formed, to which the name of Maumee was appropriately given by Dryer, in 1888.*

When the apex of the lobe had reached Defiance, Ohio, the ice front halted, or made a slight advance, and a moraine formed to mark this episode in its history. This moraine may be followed southeastward through Findlay from Defiance and northeastward through Adrian, being known as the Defiance moraine. It consists of one or more rows of rather subdued hills, passing to the west of Ypsilanti, near Northville to Rochester, where it turns northward into Lapeer county. It marks the approximate position of the ice front which was acting as a great retaining wall to prevent the water now spreading over the upper part of the Maumee valley from flowing in the natural direction of drainage. Where the waves of this lake impinged upon the land a gravel and sand beach was formed at an elevation, in the region under study, of about 220 feet above Lake Erie level, or 793 feet above tide, thus marking the approximate elevation of the surface of the lake itself. Some half dozen different names have been assigned to this beach in Ohio and Michigan, which it would cause confusion even to mention. The latest to be suggested is Maumee, as being the simplest but if two stages of Lake Maumee are to be recognized, there is no reason why one beach should be so named rather than the other. Since this same term has also been applied to the Leipsic Beach, and since they both are frequently referred to as the upper and lower Maumee, it seems best to the writer to retain one of the original names, the one most frequently used and to reserve Maumee for general use, when one or both beaches are to be designated.

According to Leverett who has now followed this beach more continuously than any other investigator, its normal height varies from five to ten feet and its breadth from ten to twenty rods. It is known to extend from Findlay, westward to Ft. Wayne and thence northeastward to Adrian, where it is supposed to have temporarily met the retaining ice wall. As pointed out by Taylor the lake was in the form of an arrow-head, with the point at Fort Wayne and a barb each at Findlay and Adrian. It is to the latter author that we are especially indebted for the facts pertaining to the lacustrine geology of eastern Michigan.[*] The distance across the barbs is about 75 miles, and about 40 miles from Ft. Wayne back to the ice wall at Defiance, where the lake is estimated to have been 60 feet deep. The lake drained southwestward from Ft. Wayne, through a now abandoned channel and entered the Wabash River near Huntington.

---

*Sixteenth Annual Report of State Geologist of Indiana, Geology of Allen County, pp. 107 to 126.

When the ice again began its retreat it withdrew from the Defiance moraine and the lake (still at the same level), filled in between this moraine and the ice wall, forming a long narrow arm, extending farther and farther to the northeast. In consequence, the Maumee Beach was continued beyond Adrian and was formed upon the inner (iceward) side of the Defiance moraine for many miles, finally reaching Imlay in Lapeer county. Thus far we are simply dealing with the gradually enlarging, first stage of Lake Maumee.

During this stage of the lake the ice front is believed to have made two periods of halt and advance, as marked in this region by the Defiance and the Cleveland moraines. The moraine designated by Taylor as the Toledo was supposed by him to pass southwestward across Monroe county around Toledo and to connect with Leverett's Cleveland moraine. This moraine could not be recognized by the writer in Wayne and Monroe counties, as a surface feature, although there is suggestive aggregation of boulders and cobbles in the eastern part of Whiteford township, which may be in the line of such a moraine. Possibly because of its waterlaid character it may have been so completely obliterated as to be easily overlooked. There is some little evidence that it strikes southeastward from Birmingham toward Detroit, where it may pass under the Detroit moraine. If this should prove to be the case it would be necessary to conclude that the ice receded from the Toledo moraine, halted and in its advance near Detroit had pushed beyond the position which it had occupied when the Toledo was laid down. Between Wyandotte and Trenton there swings in from the river a series of gentle till swells, carrying boulders and cobbles, which are believed to constitute the western edge of the Detroit moraine. Similar ridges occur on Grosse Isle with a direction a little south of west. West and southwest of Trenton these low ridges are well defined and are charged with small rock fragments. Their direction in Monguagon township is southward turning to the southsoutheast as they pass in to Brownstown and then again due south as they approach the Huron River. From the Huron southward the ridges have disappeared but there is an aggregation of cobbles and boulders to the east and southeast of Newport which proves that the Detroit moraine really extends across Berlin and the eastern part of Frenchtown to Stony Point where it enters the lake. Southwest of Brest for a mile or more there is a mere suggestion of morainic topography, the swells running east and west.

---

[*] Correlation of Erie-Huron Beaches with Outlets and Moraines in southeastern Michigan: Bull. Geol. Soc. of America, Vol. 8, page 31, 1897. The Great Ice-dams of Lakes Maumee, Whittlesey and Warren: Amer. Geol., Vol. XXIV, 1899, page 6: A short History of the Great Lakes: Inland Educator, Vol. II, 1896: pp. 101, 138, 216. The correlation of the Toledo moraine above suggested Mr. Taylor now considers uncertain. The subject is now (summer of 1900) under investigation by Messrs. Leverett and Taylor. Prof. Sherzer's proof has been revised by them so as to bring his references to them in harmony with their present information. L.

(b). Leipsic stage. When the great tongue of ice had withdrawn from beyond the present site of Imlay, ground was uncovered which was at a lower level than that of the lake itself and an outlet, northwest to the Flint River was opened. This was neither large enough, nor low enough to entirely take care of the surplus water that was rapidly supplied and the Ft. Wayne outlet also continued to serve. The level of the lake fell ten feet or more in consequence of the opening of the Imlay outlet and a new beach, known as the Leipsic was formed entirely around the margin of the now lowered Lake Maumee. During the greater part of the first stage described Monroe county was probably covered with the ice, but during the latter part of this stage and practically the whole of the second, the county was under water, about two hundred feet of which covered the site of the city of Monroe.

§ 11. Lake Whittlesey.

Beginning again its slow retreat the ice front receded in the direction of Port Huron and northeastward down the bed of Lake Erie, dividing into respectively the Huron and Erie lobes. The former withdrew as far as Port Huron and formed the Port Huron moraine, which extends from near this city, northwestward between Black River and the present Lake Huron shore, meeting at Ubly the contemporaneous moraine formed by a lobe of ice which occupied the Saginaw valley. The ice thus uncovered lower land lying between Ubly and Tyre, in the southern part of Huron county, a new outlet was formed leading southwest into the Cass River and the level of the glacial lake fell about forty feet., forming the lake to which Taylor has given the name Whittlesey. The new beach formed by this body of water stands at an elevation of 743 feet, in southeastern Michigan, or 170 feet above Lake Erie level, and is now generally known as the Belmore. It is a gravel and sand ridge from twelve to fifteen feet high and several hundred feet broad, the best defined of the entire series of beaches in this part of the state. It lies to the east of the Van Wert and Leipsic beaches and approximately parallel with them, its distance depending upon the topography of the county, but averaging from two to four miles. It enters the state from Ohio, about twelve miles west of the southeastern corner of Lenawee county, passes northward to Lenawee Junction and then turns to the northeast, passing through Ridgeway, York, Stony Creek, Plymouth etc., to the outlet noted. The "ridge," as it is called locally, cuts the extreme northwestern corner of Sec. 6, of Milan, the diagonal road following its crest for many miles between Pontiac and Adrian. A good section of the upper part of the beach is shown in a gravel pit just west of where it is cut by the Ann Arbor road, north of Milan. The section here shows at one point; 5½ inches of brown, gravelly, unstratified clay soil; 30 inches of light brown, roughly stratified clay sub-soil, becoming a deep rusty red. The clay passes into a coarse sand and this into fine gravel, with some pebbles as large as hens' eggs. This gravel is well stratified; 6 inches of perfectly stratified, fine sand; 10 inches of grit, obliquely laminated; 1 inch layer of fine gray sand mixed with some clay; 48 inches of stratified gravel, with the strata dipping towards the lake side. The gravel is very fine towards the upper part of the bed, becomes gradually coarser and then finer. One layer is thoroughly washed from fine sediment and is loose and open, the remainder of the bed has more or less sand.

Total thickness of section equals 8 feet 4½ inches.

The farmers living upon the beach very generally report that the gravel layers extend to a depth of twelve to fifteen feet and that water is readily secured from the lower beds.

Owing to the inaccessibility of the early geological reports of the state, credit is not usually given Bela Hubbard for his observations upon the surface geology of the region and for his sagacious interpretations of the same. The Belmore Beach he had followed for many miles and in 1840 he described it under the name

"Ancient lake ridge,* as a continuous gravelly ridge having a course parallel with the present shore of Lake Erie and the Detroit river. He observed its structure and the sudden change which it marks in topography, the surface to the east being low and flat, while that to the west is more elevated and rolling. He recognized the differences also in the character of the soil and of the timber upon opposite sides of the beach. The elevation he gave erroneously as 107 to 108 feet above Lake Erie but he clearly saw that it marked the level of a great sheet of water. The difficulties in the way of such an interpretation were stated to be in accounting for such a supply of water and in finding barriers capable of confining it. The possibility of an Appalachian uplift across the St. Lawrence and the Highlands across the Hudson, serving as barriers is suggested, in which case

> "a single communication only would then exist with the ocean, viz.: through the valley of the Mississippi. * * * That the lakes once discharged their waters in this direction, such additional evidence is furnished by the appearance of the country, that in this our argument but serves to add confirmation to the general opinion."

The existence of a barrier at Mackinac, cutting off Lakes Michigan and Superior, with the closing of the outlet to the Mississippi would cause the level of the water to rise until it would break through the Mohawk and Hudson and finally through the St. Lawrence. (p. 106.) From fossils found in the Saginaw and Niagara valley deposits he concluded that the water was *fresh*, although he suggests the probability of a subsidence to ocean level, with barriers cutting off the influx of the sea and "disproportionate elevations." In the report above referred to, a topographic map of Wayne county is published, the work of S. W. Higgins, upon which the Belmore Beach is located. Instead of entering Livonia township at the northwestern corner of Sec. 18 and cutting diagonally across Secs. 7 and 5 the beach is represented as following the town line north between Livonia and Plymouth. This error arose from the fact that the Maumee Beach leaves Wayne county on this town line and the two beaches were, in consequence, confused. A glance at the drainage of the region should have made the error apparent. Hubbard followed the beach across Oakland and Macomb counties, into St. Clair, and discovered a number of other inferior ridges between this and the Lake Huron shore. On his map of Lenawee county issued by the Geological Survey it is traced from a quarter of a mile south of the northeast corner to Sec. 19, Palmyra township. "This ridge is from 10 to 20 feet high, the former boundary of the lake shore composed of sand and gravel." The strip of land lying between the Belmore and Maumee Beaches, including the extreme northwestern corner of Monroe county, was uncovered by water during the existence of Lake Whittlesey and gives evidence of long continued surface erosion. This feature, combined with the great strength of the beach, leads to the conclusion that this lake persisted for a relatively long time.

---

*H. R., No. 8, p. 102; H. D., No. 27, p. 278; S. D., No. 7, p. 138.

§ 12. Arkona beach.

The recession of the ice front from the Port Huron moraine opened an outlet, or series of "spillways" from fifty to sixty feet lower than the level of Lake Whittlesey. The position of these outlets was located by Taylor across the "thumb" north of Ubly rather than around it to the north, and correlated hypothetically with this beach, so that the general direction of drainage of the former lake was continued. The great difference in level between this body of water and that of Lake Whittlesey, with the consequent changes in form and drainage, justify its separation from the latter lake. The fact that it was not confluent with Lake Saginaw seems a ground for not regarding it as simply an early stage of Lake Warren. See Part II of this volume, upon Huron county.

It seems probable that this stage in the lake history continued only while the ice was retreating from the Arkona outlets to the position it occupied when Lake Warren was formed. This was of relatively short duration and the beach, so far as it has been followed in Michigan, is of a weak, tortuous character. In Wayne, Monroe and Lenawee counties it is a rather wide, but flat sand ridge, from two to four feet above the general level. Broad areas of pebbly sand are occasionally associated with the faintly developed swell of sand, and cuts into it at the roadside show fine gravel layers to a depth of from two to three feet. From the beach lakeward there is a gradual surface slope apparent, by which the Arkona may be recognized aside from the materials of which it is composed and its surface elevation. Aside from its weak development the beach is peculiar in the fact that it does not take a direct course. It seems to have simply followed its surface contour, its course being determined very largely by the topography instead of determining the topography. An inspection of Plate VII shows the beach entering Monroe county from Washtenaw, about 1¾ miles east of the village of Milan. It passes southwestward across Milan and Dundee townships, following closely the 690 foot contour, but lying to the west. Leaving the county in Sec. 6 of Summerfield the topography causes it to make a curve to the west in Lenawee county, crossing the Raisin and reëntering Summerfield township south of the river in Sec. 18. It then passes eastward to the south of the river road and turns northeast toward Petersburg. Southward for nearly three miles its sand is mingled with that of the next lower, or Forest Beach. In Sec. 21, it swings westward, leaves the county again and makes another but larger curve to the west owing to the relatively depressed and very flat character of the surface in southern Summerfield and northern Whiteford townships and the adjoining portions of Lenawee county. From Dundee township, through Summerfield the sand has been heaped into mounds and ridges through the agency of eastern winds. According to Spencer the beach extends westward to Blissfield where it has the same duny character and an elevation of 694 feet. It then turns eastward and makes a regular curve in the southwestern corner of Whiteford, west of the railroad. It here consists of a rather well defined swell of gravelly sand, the dunes seen to the west and north having disappeared. The beach turns westward, and enters Ohio from the southeastern corner of Lenawee county. Through this region it is separated from the sand of the Forest by a belt of heavy clay. In his map of the raised beaches north of the Maumee River* Gilbert did not recognize this as a separate beach. It enters Ohio between his third and fourth beaches about five miles east of the northwest corner of Lucas county. It is not improbable that to the southwest it may be incorporated in the broad belt of sand mapped as the Fourth Beach. Spencer gave the elevation of the Arkona at Dentons, on the Michigan Central in Wayne county, the same as at Blissfield, 694 feet, and this appears to be approximately correct. It would seem as though a very few years would suffice to construct a beach of such strength. In places a miniature ridge was observed, running parallel with the main one, but one-fourth of a mile distant, on the lakeward side, and from two to three feet lower. While this stage of the series of ice-dammed lakes persisted that portion of these townships lying to the west of the beach was above water. Over Monroe City the water stood from 100 to 105 feet deep.

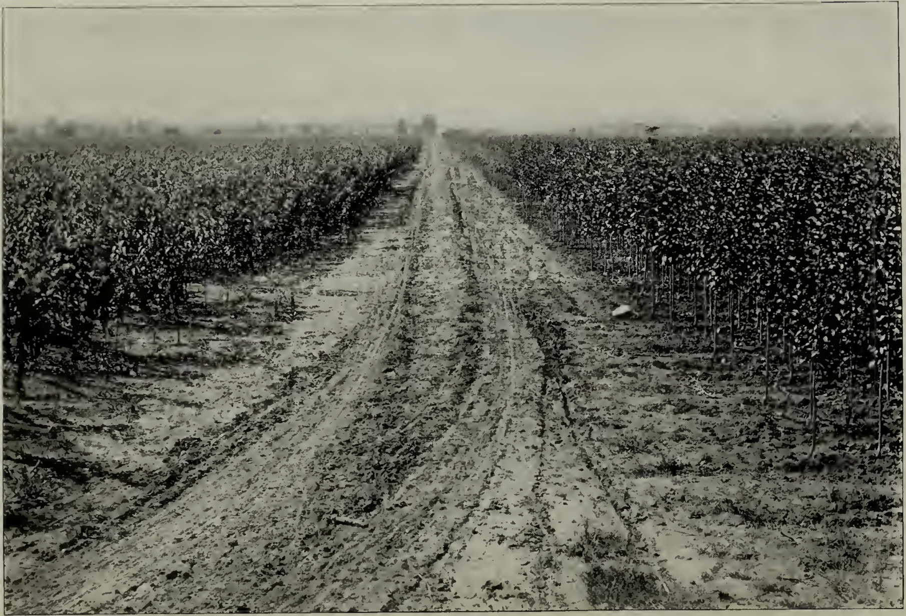
---

*Geol. Survey of Ohio, Vol. I, 1873.

§ 13. Lake Warren.

(a). Forest stage. From near Sylvania, in Ohio, there enters Monroe county a broad belt of heavy yellow sand which was termed by Gilbert, in 1873, his beach No. 4. This he regarded as representing a gradual subsidence of the glacial water from 90 to 60 feet. In Bedford township this belt divides into two, as shown upon Plate VII, the main part of which passes northward through Ida, Dundee and London townships, lying between the contours of 90 to 80 feet above Erie level. This strip of sand has been called the Forest Beach by Spencer and it outlines a great sheet of water to which has been given the name Lake Warren. So far as seen in Monroe county there is no well defined ridge, as in the previous cases, but simply a belt varying in width from four to seven miles, over which the loose sand has been heaped by the wind into mounds and ridges. Some of these ridges continue for several miles and attain a height of twenty to twenty-five feet. In places heavy double ridges occur, parallel with the shore line. This Forest Beach cuts the southeastern corner of Washtenaw county, passes across Wayne county, intersecting the Michigan Central road at Wayne station, and continues northeastward by Port Huron into the "thumb." The elevation of the rail at Wayne is 87 feet above Erie level and this marks approximately the center of the belt. In passing northeastward from Dentons to Goodells, west of Port Huron, the Arkona rises seven feet owing to a differential uplift. In this vicinity the Forest has an elevation of 92 feet above Erie (665 above tide, according to Spencer) and if we assume the same differential movement the Forest in Wayne, Washtenaw and Monroe counties would have an elevation of 85 feet above Erie, or 658 feet above tide.

As the ice front retreated from the Port Huron moraine, beyond the place at which the Arkona outlet had been opened, it made its next halt and slight readvance along a line extending from the point of the "thumb," northwestward through Harrisville and Alcona, in a curve to Petoskey, depositing the Alcona moraine. As the ice moved down the northern slope of the "thumb" a series of temporary outlets were opened into the Saginaw valley, and finally the waters in front of it thereafter known as Lake Warren became confluent with those of Lake Saginaw. (See Part II of this vol-



MONROE NURSERY, TYPICAL OLD LAKE BOTTOM, AND WAVE-WASHED FLAT.

ume, Geology of Huron county, Fig. 4, Plate VIII.) According to the observations of Gilbert, Taylor and Lane the Forest Beach in this northern region is characteristically double, showing two well defined gravel and sand ridges, with a difference in level of eight to fifteen feet. In the southeastern part of the state it is very probable that similar beach ridges were also formed, which were later covered by shifting sand and completely obscured. The shape of Lake Warren during this stage was such that with a prevailing northeast wind the waves would strike with greater force upon the shelving shore of southeastern Michigan, than upon the "thumb." A greater amount of sand would thus be tossed up by the waves and carried inland. The common outlet of the Saginaw and Warren lakes is known to have been through the Pewamo channel, extending from Maple Rapids, by Pewamo, Muir, and Ionia to the Grand River. This channel is fifty miles long and from three-fourths to a mile wide, with a fall to the southwest of not more than a foot to the mile. Through this outlet the waters of all the glacial lakes described, except Lake Maumee in its first stage, drained to Lake Chicago, thence through the Chicago outlet and on to the Mississippi.

(b). Grassmere stage. A second beach, not hitherto recognized in this region, branches from the broad belt of sand which enters Bedford township from Ohio, and passes northeastward through Erie, La Salle, Monroe, Frenchtown and Ash townships (See Plate VII). As seen in Monroe and Wayne counties it consists of a belt of yellow sand, from two to three miles in width, covered with heavy ridges and knolls between the contours of 610 to 620 feet above tide (37 to 47 feet above Lake Erie level). It is the reduced counter part of the Forest Beach and was made by Lake Warren after it had suffered a drop in its level of about 43 feet, caused by the clearing away of some obstruction in its outlet. That the drop was not sudden is evidenced by the fact that this beach is connected in places with the Forest by light coverings of sand and but little heavy surface clay separates the two. The drop from this stage of Lake Warren to the present Lake Erie level, a distance of about 42 feet, was apparently much more rapid. Plate XI gives a view of one of the heavy ridges of sand seen just west of Erie.

These are abundant and characteristic from the Ohio line to Dearborn, as far as the writer has followed the beach continuously. According to the Michigan Central profile the approximate elevation of the central portion of the belt is 615 feet A. T. and at Carleton about the same. In his survey of Huron county (See Part II of this volume) A. C. Lane has identified a series of beaches which are at the right elevation, below the Forest, to include this one. To this series he has given the name Grassmere. The subjoined table shows at a glance the main facts pertaining to the glacial lakes of southeastern Michigan. The glacial history outlined thus briefly in this chapter furnishes the key to an understanding of the physical features of Monroe county. It accounts for some peculiarities of the rock surface, the nature and distribution of the materials which cover the bed rock, and the surface topography with attendant drainage. All parts of the surface were successively subjected to wave action which cut down prominences and filled in depressions. A layer of sediment was spread over the entire county, thin to the west, thicker towards the east and southeast. This consists of a dark colored, finely divided clay, generally free from pebbles. A good impression of the effect of this action upon the topography is shown in Plate XIII. Much of this was removed by wave action as the water receded and much of it has since been removed by surface erosion, so that in many portions of the county the pebbly till reaches the surface, or is covered by only a few inches of vegetable mould. Over these regions the surface boulders are only slightly imbedded, while in the eastern and southeastern portions of the county the deposit is thicker and the boulders generally covered. The thickness observed in a number of places varies from two to three feet, and the maximum in Erie township is undoubtedly much greater. From the crest of "stony ridge" this deposit has been removed very largely through erosive agencies. The source of this clay was the till, from which the sand and pebbles were removed by waves and thrown upon the beach, while the finer clay particles were held in suspension, carried lakeward and deposited in the deeper water. The clay used in the Monroe brickyard must have sand added to it before it is suitable for brick and tile. In front of the Arkona beach in the southwestern part of Dundee township there are patches of wave washed till from which the waves removed the sand and fine clay but were not strong enough to disturb the pebbles. In consequence the soil is full of small pebbles and the beach is very largely composed of sand.

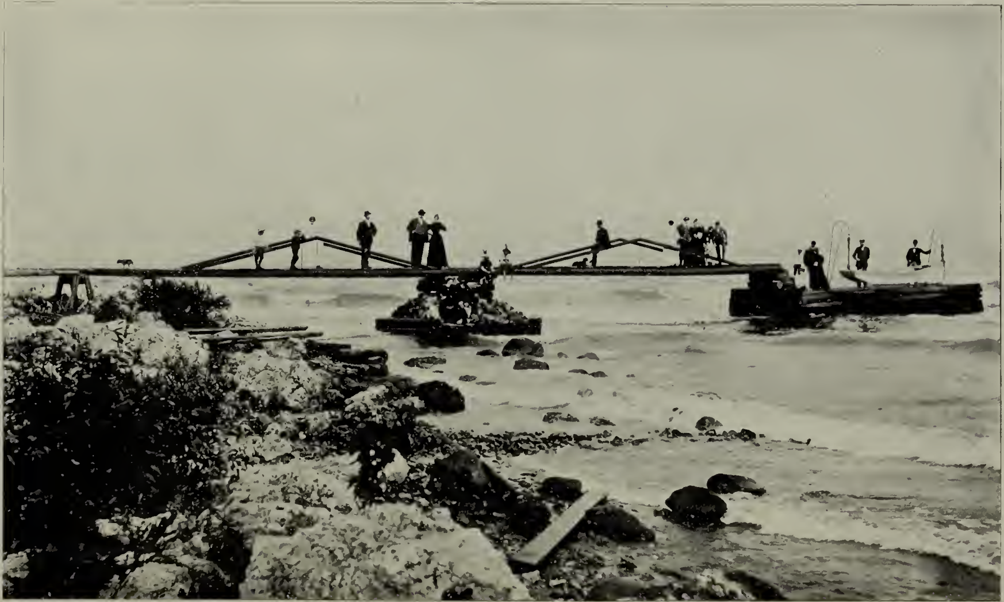
TABLE VIII.—FORMER LAKE BEACHES IN MONROE COUNTY.

Name of lake.	Outlet.	Location of ice dam.	Name of beach.	Elevation of beach in Monroe county.	
				Above tide.	Erie level.
1. Maumee—					
a. Van Wert stage	Fort Wayne	Defiance and Cleveland moraines.	Van Wert	793	220
b. Leipsic stage	Fort Wayne and Imlay	Detroit moraine	Leipsic	783	210
2. Whittlesey	Tyre Ubly	Port Huron moraine	Belmore	743	170
3. Arkona	Spillways, Huron county.	Between Port Huron and Alcona	Arkona	694	121
4. Warren—					
a. Forest stage	Pewamo	Alcona and Hagensville	Forest	658	85
b. Grassmere stage	Pewamo and-?	Hagensville and northward	Grassmere	615	42

This table has been revised by Leverett and Taylor. L.

§ 14. Lake Erie.

The withdrawal of the ice sheet from the St. Lawrence valley, opened an outlet for the great lakes to the east and the level of Lake Warren fell sufficiently for Erie to separate from Lake Huron. The three upper great lakes were still confluent, forming the great Lake Algonquin which drained into Lake Erie as at present. The still further retreat of the ice from the Ottawa valley, opened an outlet through Georgian Bay, Lake Nipissing and the Mattawa valley, lowering the level of Lake Algonquin to what Taylor has named Nipissing Great Lake. During the existence of this latter lake its drainage was through the Ottawa River, and Lake Erie alone drained into the Niagara River, and supplied the water for the falls. During this time the level of Lake Erie was lower than now. A differential elevation of the region to the north finally cut off the flow through the Nipissing-Mattawa River and the St. Clair and the Detroit rivers again became the line of drainage bringing the present great volume of water into Lake Erie. The elevations and fluctuations of the level of the lake, so far as data have been obtained, are given in the preceding chapter. It seems necessary to conclude from the nature of the Warren beaches that the prevailing wind was from the east or northeast. During the Erie stage it has been from the opposite direction and, although there is a sand ridge bordering the lake for a considerable distance, the sand has not generally encroached upon the land. Between Stony Point and Point aux Peaux there occurs the outcrop of dolomite previously referred to and for this distance there is a gravel beach of rather angular fragments. (See Plates XII and XIV.) The crest of the ridge here is about six feet above the water level and from 30 to 35 feet back from its edge, making the slope quite steep. For the greater portion of the distance between the points there is a belt of sand from five to twenty feet broad, which skirts the water's edge, and in places extends well up the gravel slope. In the water itself there is a strip of fine to coarse gravel, mixed with sand. Landward from the crest of the gravel ridge the inclination downward is more gradual, giving a slope from 50 to 60 feet in breadth, which passes into a low marshy strip, supplied with water from the lake during times of storm. This marsh is, in general, very extensive, covering thousands of acres, and three areas may be recognized, separated by more highly cultivated land about the mouths of Stony and Otter creeks. These have been converted into hunting preserves



MONROE BEDS AT POINT AUX PEAUX, MONROE COUNTY.

and at certain seasons water fowl are abundant. The Point Mouillée marsh extends from the mouth of the Huron to Stony Point. The Monroe marsh begins about a mile south of Brest and extends to the mouth of Plum Creek. The Erie marsh, with interruptions, extends from near Otter Creek to the Ohio line, broadening in places and including patches of open water. Figs. 5 and 8 (p. 199) give views of the last two regions. Shelving off gradually from the beach there is a strip of sand which extends lakeward. The three fathom (18 foot) contour upon the government chart extends out 4½ miles from the north cape of Maumee Bay, and gradually approaches the beach until opposite Stony Point and Point aux Peaux, where it is but one-sixth of a mile out. Northeastward it again pushed lakeward by the deposits from Mouillée Creek and the Huron River.

§ 15. Recent submergence.

Extending backward from the lake for a distance of three to four miles, the Huron is practically a stagnant stream, with an ebb and flow as the easterly winds drive the water in from the lake. A difference of two feet in the level of the water in this part of the river may thus be produced. The Lake Survey chart gives the soundings for a mile back from the mouth, which in the channel range from 10 to 16 feet. Residents say that there are holes in the bed 25 feet deep, from one to two miles back. In an early day lake craft were built at Rockwood, four miles from the lake, and with a little dredging this village could be made a lake port. In its present condition, with no current, the Huron is incapable of cutting such a channel. Further, it meanders over this low plain, showing that at one time there was some cutting and hence some current. Its condition is that of a "drowned stream." The same phenomena are shown, to a greater or less extent, by all the streams which enter the lake from Monroe county. The Raisin empties into the lake by several mouths, the central one of which was converted into a canal by the general government in 1835. A view of this is shown in Fig. 4, giving one a good impression of the inundated appearance of the region. One of the channels to the south of the canal, for a distance of two miles, averages 8½ feet in depth. Back from the lake ¼ mile a depth of 12 feet is shown upon the chart, while in the lake itself the depth is but two to three feet. Referring to the Raisin the coast chart says, "depths at this harbor vary but little from year to year, but dredged channels outside of piers are not permanent." It is probable that the ebb and flow from the influence of the lake serves to keep the channels open, but could not have originally produced them.

Another good illustration is furnished by Halfway Creek, which empties into North Maumee Bay in the southeastern part of the county. Attention was called to this in 1873 by Gilbert in the Ohio report.* Slack water was said to begin seven miles from its mouth. One-half mile from the bay the stream is sixty rods wide, with a central channel four rods wide, fifteen feet deep, and with its banks seven feet under water. Back where the slack water is first noticed the channel is twenty feet wide and six feet deep. The lake chart now shows a well defined submerged channel running back three miles from the bay and averaging 9.4 feet deep, with a maximum of 14 feet. This channel extends into the bay, giving soundings of 7, 10, 8 and 13 feet, through a strip over which the water ranges from 4 to 5 feet. Similar phenomena have been observed by Taylor in the streams which empty into the Detroit and St. Clair Rivers, and into Lake St. Clair.†

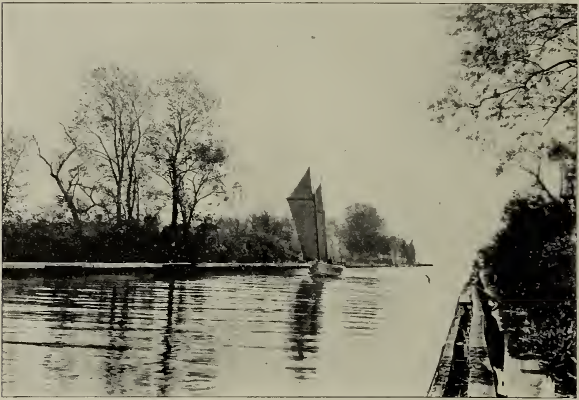


Fig. 4. View of the government canal, near Monroe, opening into Lake Erie. The view gives one an idea of the inundated "drowned" appearance near their mouths of all streams which empty into Lake Erie.

---

*Vol. I, Geology, page 555.
†Proceedings Amer. Assoc. for the Ad. of Science, 1897.

The explanation is that all these streams, in comparatively recent time, flowed to a lower base level and were thus given sufficient velocity to cut their channels and erode their banks. According to the conclusions of the above author this occurred during the Nipissing stage, while the drainage of Lakes Superior, Michigan and Huron was through the Ottawa River, leaving the bed of the Detroit River practically empty and, probably, much lowering the present level of Lake Erie.* When the present drainage was restored the strip of land bordering the river and lake would be again covered with water, much of the beach would be rendered marsh and the mouths of the rivers, for a considerable distance back became submerged, *drowned*, as shown in Fig. 4.

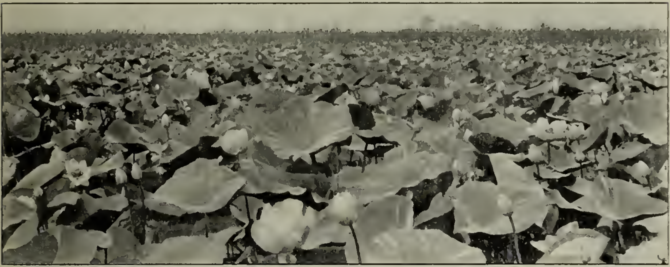


Fig. 5. Lotus bed in the marsh near Monroe. The marsh is due to recent submergence by the lake. Photographed August, 1890.

E. L. Moseley has shown† that this recent submergence accounts for the fact that the plants of the islands north of Sandusky Bay are the same as on the shore. He also calls attention to the fact that upon these islands are caves whose stalactites extend into the water, while the stalagmites are below the water 3 or 4 feet, and gives data regarding submergence of walnut stumps, etc.

D. Post-Glacial Warping.

§ 16. Recent production of stony ridge.

The " stony ridge" which has frequently been referred to as a low anticline in the dolomites, passing from Sylvania northeastward through Monroe, gives evidence of having been produced since the withdrawal of the ice sheet. The deposits of till which overlie the rock appear to be conformable, to a greater or less extent, with the rock strata. There is produced, in consequence, a subdued swell in the surface topography, having a breadth of one-half to two miles and a maximum height of 12 to 15 feet. Had the formation of the rock anticline occurred before the Pleistocene deposits had been laid down we should expect no trace of it in the surface features. In Jefferson and Chautauqua counties of New York, Gilbert found similar low anticlines which he believed to be of post-glacial origin. These were described before the American Association for the advancement of science under the title "Some New Geological Wrinkles."* They were believed to have been caused by the lateral expansion of the superficial rock-strata as their temperature rose in consequence of the post-glacial amelioration of climate.

---

*Origin of the Gorge of the Whirlpool Rapids at Niagara. Bull. Geol. Soc. of Amer., Vol. 9, 1898, page 84.

†The Lakeside Magazine, Lakeside, Ohio, April, 1898, Vol. I, pp. 14-17.

---

*Proc. Amer. Assoc. for the Ad. of Science, Vol. XXXV, 1886, page 227.

CHAPTER VII.

SOILS AND SUBSOILS.

A. *Nature, Origin and Varieties.*

§ 1. Preglacial soils.

The different types of soil and their formation may be explained most simply by discussing first the effect of the various soil producing agencies upon the bed rock of the county. In determining what change occurred and what substances were produced during the countless ages that these rocks were exposed to the action of the air, rain and frost, it will be possible to bring into view again the original soil materials, with which the rocks were covered, and of which they were so thoroughly dispossessed by the ice sheet. One of the simplest transformations of rock into soil took place in connection with the St. Clair shale, in the northwestern part of the county. The material of which this formation is composed represents the indestructible elements of land areas, carried to the off shore region by streams, waves and ocean currents. It was completely altered, hydrated and deprived of all soluble ingredients. When elevated and exposed to atmospheric and aqueous agencies the principal change was purely a physical one, resulting in its softening and disintegration. There would result a heavy, compact clay soil. Other materials similarly introduced, would give character to the soil and add greatly to its fertility. Organisms which secrete calcium carbonate from the sea water would have become embedded in the ooze of the sea bottom and would add this substance, along with sulphur and iron. In weathering the iron would oxidize and stain the soil a brown or yellow. There must have existed then in the northwestern part of Milan township and adjoining portions of Lenawee and Washtenaw counties a dark brownish yellow or green, compact clay soil possessed of considerable fertility and lasting qualities. To the east of this small area, over the Traverse belt (see Pl. I), a somewhat similar soil resulted from the disintegration of the shales of this formation. It was, however, of a more bluish color and much richer in calcium carbonate because the shales themselves are richer in this substance and because of the interstratified layers of limestone.

A far greater change than that just described would take place in the case of the pure limestones of the Dundee formation which after exposure for a very great period would be unrecognizable. This alteration results largely from the solution of the carbonates of calcium and magnesium. Pure water cannot dissolve much of either of these substances, but when it contains carbon dioxide gas these carbonates are readily taken into solution as bicarbonates in proportion to the amount of this gas present. Ordinary rain water contains from .22 to .45% of this carbon dioxide by volume, but after percolating through a bed of vegetable mould this amount may be greatly increased. Expressed chemically the change by which the calcium carbonate is thus readily taken into solution is shown in the following equation:

$$Ca\,CO_3 + H_2O + CO_2 = Ca\,(H\,CO_3)_2.$$

In solution the bicarbonate is carried to the sea where the myriads of organisms may break up this unstable compound, retain the calcium carbonate and liberate the carbon dioxide which will escape into the atmosphere to be again utilized in the destruction of the limestones exposed to its influence. By the leaching out of the carbonates the impurities present in the limestone are gradually concentrated and there results a mealy, siliceous clay, generally stained more or less red with iron oxide. Looking at the composition of one of the beds in the Christiancy quarry:

Calcium carbonate	86.80%
Magnesium carbonate	11.60
Iron and alumina	.12
Silica	1.10

it will be evident that the proportions of silica, iron and alumina will increase in the residue as the carbonates are slowly dissolved. The percentages of the latter may be reduced to simply a fraction of one per cent, or to a mere trace. Usually, however, the amount of carbonate left behind is considerable, and there results a calcareous soil. One foot of such soil might represent the destruction of one hundred feet of limestone, involving an enormous period of time. The following analyses from Merrill's "Rocks, Rock-weathering and Soils" (page 359), show at a glance the changes that have thus been produced in a bed of pure Trenton limestone:

	Unaltered limestone.	Soil from same.
Silica (SiO_2)	0.44%	43.07%
Alumina (Al_2O_3)	0.42	25.07
Ferric oxide (Fe_2O_3)		15.16
Lime (CaO)	34.77	0.63
Magnesia (MgO)	Trace.	0.03
Potash (K_2O)	Not determined.	2.50
Soda (Na_2O)	Not determined.	1.20
Carbon dioxide (CO_2)	42.72	Trace.
Water and organic matter	1.08	12.98

By an exactly similar process the dolomites which overlie and underlie the Sylvania sandstone gave rise to a soil in every respect similar. These changes are seen to be in progress at the Woolmith, Raisinville, Davis,' Cummins' and Plum Creek quarries, where the upper layer is softened and whitened and has a mealy look and gritty feel. No appreciable quantity of such soil has been formed, however, since the retreat of the ice, thus testifying to the recentness of this event or to the extreme slowness with which this change takes place. (See Pl. III.) A much simpler change would have occurred in the case of the Sylvania bed, which consists so largely of pure quartz grains. The small amount of calcium and magnesium carbonate which serves as a weak cement, would be dissolved and there would be formed a loose bed of sand, which from the absence of iron must have long remained of a pure white color. Such a soil could have supported only the scantiest vegetation and would eventually become stained with organic matter. It will be seen that the soil deposits which mantled the rock before the glacial episode were dependent for their character directly upon the bed rock itself and could have been traced by imperceptible gradations into it. Clay soil, with more or less silica and iron, covered the greater part of this county, gradually growing darker and heavier towards the northweastern part of Milan. The clay areas were separated by a white sand belt, diagonally crossing the county from southwest to northeast, and varying in width from one-half to four miles.

§ 2. Glacial subsoils.

No sharp line of division can be drawn between soil and subsoil, but by the latter term is commonly meant those loose deposits which are beyond reach in the ordinary processes of cultivation, say from eight to twelve inches deep. The subsoil of Monroe county consists very largely of the previously described till, the "ground moraine" of the great ice sheet. This consists of compact, unstratified, stony clay produced by the grinding of the bed rock over which the ice sheet moved and of the fragments which the ice was transporting. Without doubt the preglacial soils formed enter into the composition of this till to a greater or less extent. A deposit with such a history must obviously contain the greatest possible variety of materials, and be somewhat independent of the underlying rock strata. Such soils have been termed "residuary soils," or "soils of transportation," to distinguish them from the previously described "soils of disintegration." The former are characteristic of glaciated regions, the latter of regions not subjected to such ice action within recent geological time. Prof. W. O. Crosby has made a mechanical analysis of the till found in the vicinity of Boston and finds it to consist of 25% small pebbles, 20% of common sand, 40 to 45% of exceedingly fine sand, essentially quartz, and but 12% genuine clay, (alumina). It is quite probable that this represents approximately the composition of Monroe county till. Lenticular masses of stratified sand are found embedded in the clay and less frequently layers of gravel. Near the surface, within reach of percolating surface water, the iron compounds become oxidized and the till assumes a yellow, brown or red color. Otherwise it is of a characteristic blue color. At Dundee the discoloration of the clay is said to extend to a depth of 14 feet. In some of the stream cuts in Milan township the alteration of the till extends from 1½ to 3 feet only, and this would perhaps represent an average for many portions of the county. In Sec. 33 of Berlin there is said to be 15 feet of light colored clay and 5 feet of blue clay above the rock.

In many portions of the county the subsoils consist, in part, of the lake sediments and beach deposits described in the preceding chapter. A phenomenon for which we have no explanation at hand, was reported by a considerable number of farmers. They assert that, in the case of the isolated sand knolls, common about the margins of the sand belts, the underlying clay is blue and its surface the reverse of that of the upper surface of the sand, that is, concave. This gives the mass of sand a lenticular form and water accumulates in the clay basin so that such knolls are very damp and backward in the spring. They can be drained by simply cutting a ditch through the rim of this basin upon the lower side. Captain Richard Ingersoll, Sec. 22, Dundee, says that the clay upon his lower land can be worked two weeks earlier in the spring than can these knolls. The clay encountered beneath the sand is reported as hardpan. This phenomenon was reported in Secs. 26 and 18 of Dundee and in Raisinville and Summerfield townships.

§ 3. Post-glacial soils.

Without attempting too fine a classification we may say that the Monroe farmers have to deal with five types of soil, which may shade into one another by imperceptible gradations; sand, clay, loam, silt and muck. From what has just been presented the source of the materials for these soils and the method of their formation will be readily comprehended.

(a). Sand and gravel. The great belts of sand, with limited patches of gravel, shown upon Pl. VII and described in the preceding chapter, have been produced by the wave action of the various bodies of water which covered the region after the withdrawal of the ice sheet. About the margins of this series of lakes and for some distance lakeward where the water continued shallow, the waves loosened and softened the till. A sorting of this material began at once, the coarser sand grains and small pebbles were worked shoreward and at times of the heaviest storms, were tossed back upon the beach in the form of a continuous ridge. The retreating wave, when its force had been spent, would drop first the heavier pebbles and carry back for a short distance the sand particles. In this way the beach ridge would be formed of gravel mostly, with a belt of sand upon the lake side. The separate particles, in the course of a year, would be moved backward and forward many times, some of them traveling miles, and owing to mutual attrition would have their corners and edges rounded. In certain places, out from the beach, as in Secs. 21, 22, 15 and 16 of Dundee the force of the waves was not sufficient to move the pebbles shoreward, the sand and clay particles only were removed and the pebbles accumulated on the till. For the same reason they seem to congregate wherever water drips upon a soil through which pebbles are disseminated. While the beaches of Lake Maumee, Whittlesey and Arkona were forming, a lake deposit was being spread over the central and eastern part of the county which covered the till and the boulders lying upon its surface. When the waters had fallen to the level of Lake Warren, the wave action would be directed very largely against this later deposit, instead of the till itself, and would find comparatively little material from which to construct a gravel beach. For this reason we find more gravel in the Belmore, less in the Arkona, and still less in the Warren beaches.

From the distribution of the sand over the region to the west of the Forest and Grassmere beaches it is to be inferred that the prevailing and heaviest winds during this stage were from the east, northeast, or southeast. As the beach ridge of sand was formed by the action of the waves, its loose particles after drying would be seized by these winds and gradually moved landward, until the belt of sand was from three to seven miles broad. It is just this action that now occurs along the eastern shore of Lake Michigan owing to the prevailing northwest winds, while the western shore is comparatively free from such sand accumulation. The sand from the Warren beaches was thus spread over thousands of acres of land, impoverishing the soil and those unfortunates who are compelled to get their living from it. Low cabins, puny barns, bony stock, poorly clad and half starved children; all are because the prevailing direction of the wind, a few thousand years ago, was easterly. At present the prevailing direction of the wind is from the opposite point of the compass and the Lake Erie sands are not encroaching upon the fertile soils adjoining. To summarize then, the sand and gravel of the county were derived originally from the crystalline rocks to the north and east, washed out of the till by wave action around the margins of the lakes and still further distributed by the wind.

(b). Clay. While the action just described was in progress in the littoral region of the lakes, the finer particles of sand and alumina were taken in suspension and carried lakeward by the waves and currents. This material would settle very slowly into the deeper and quieter portions of the water and form the clay deposit previously referred to as covering the bottom of the lake. This would fill up all irregularities of the till surface and slope very gradually and evenly toward the southeast. The particles were so nearly homogeneous in size and distribution that no distinct stratification is visible. The vegetable growth upon the lake bottom became embedded in the clay and gave it a dark color. This deposit would necessarily be thinner in the western and thicker in the eastern part of the county, where it covers the surface boulders. That which was originally deposited over the central portions of the county was very largely removed, as the waters receded, and was carried further eastward. This clay is very sticky when wet, consists of alumina and silica in finely divided particles, contains enough iron to burn red and was derived from the till. Small streams entering the lake from Lenawee and Washtenaw counties would contribute some sand and clay to the Monroe deposits, but they were derived from the surface till of these regions.

(c). Loam. This term is applied to a mixture of sand and clay, which either owing to the proportions of the ingredient, or to the size of the constituent particles, is looser and less compact than clay itself. When wet it is not so sticky, and upon drying does not bake and crack. As the proportions of clay and sand differ, varieties are distinguished which graduate into one another, and into other types of soil. When the plant food products are present it forms an ideal soil, because of the ease with which it can be worked and of its ability to conserve just the proper amount of moisture for plant growth. Owing to the presence of organic matter it is very commonly of a dark color. Narrow strips of this soil occur along the margins of the clay and sand belts where the two have become mechanically mixed through the action of wind and water.

(d). Silt. Along the margins of all the streams, constituting their flood plains, is a deposit very similar in its physical properties to loam. It usually differs from it, however, in having a much greater variety of material present, since it represents the surface wash from all the regions drained by each particular stream. It is distinctly stratified and contains the shells of both water and land snails and other molluscs. Owing to its great fertility it supports an abundant vegetation which gives it a dark color. The larger streams furnish the broader areas of this type of soil, and in some regions dikes have been constructed around the fields to shut out the streams completely at times of flood. In composition the typical river silt consists of 50 to 70% of sand, about 10% each of alumina and organic matter, with varying quantities of iron, calcium, magnesium, potash, soda and phosphorus. Their general nature is shown by the two analyses* given below from the bottom lands of the Raisin just over the western boundary of the county, at Deerfield. The first analysis is of silt which had been under cultivation for 40 years, without manuring, the second represents the "virgin soil." The timber in both cases is ash, basswood, hickory, walnut and oak.

---

*"Michigan Soils." Bulletin 99 of the Michigan Agricultural College, page 6.

	Cultivated.	Uncultivated.
Sand and silicates	58.17	62.42
Alumina	6.48	10.64
Oxide of iron	7.62	3.42
Lime	1.92	2.10
Magnesia	1.43	1.59
Potash	1.84	2 05
Soda	1.20	1.19
Sulphuric acid	.32	.24
Phosphoric acid	.40	.41
Organic matter	*10.97	+9.39
Water	9.45	6.08

*Nitrogen =.42.
+Nitrogen =.37.

(e). Muck. One characteristic of a glaciated region is the presence of innumerable basin like depressions, in which spring and surface water may accumulate, but from which it cannot readily escape, except by evaporation. Many such spots are found in the sand belts, where the sand is thin and underlain by clay. Small lakes are here formed in which plants, drawing their sustenance from the water and air, get a foothold and eventually add their remains to the soil of the bottom and margin. Coarse varieties of moss presently start, which dying beneath and growing above prepare a bed for the rushes, the water lilies, and the water-loving shrubs. Through the agency of water fowl animal life might be introduced, the decay of which would furnish other ingredients to the soil accumulation upon the bottom. Some clay and sand would be washed in from the surrounding region, so that through all these agencies the lake would be slowly filled and converted into a marsh. New types of plant life would now find suitable conditions, the filling process would continue and a meadow finally result, capable of cultivation. The black, spongy, carbonaceous mass, resulting from the alteration and partial preservation of the organic matter, is called *peat* when practically pure. Usually it is mixed with clay and sand and is then known as *muck*. It is rich in nitrogen and phosphorus, but does not contain sufficient body to serve as a soil for most plants. The total amount of such soil in the county is not great although small areas are numerous in certain regions. A cranberry marsh covering 112 acres is located in the S. E. ¼. Sec 24 of Summerfield township, belonging to Clayton Everett, of Toledo. This is flooded in the spring as shown in Fig. 6 but is drained and later irrigated by numerous wells, from which the water is pumped by windmills. An extensive peat bed occurs in Sec. 9 of London township, 60 acres of which belong to the Ilgenfritz Nursery Co., of Monroe. A crop of *Sphagnum*, the moss concerned mainly in the production of peat, is harvested from it each season and used in packing about the roots of nursery stock for shipment. It holds moisture well, is light and does not "heat." In 1838 Hubbard reported a soil of fibrous peat one to two feet thick as covering 18 sections in Ida, 9 in Summerfield and 5 in Whiteford.

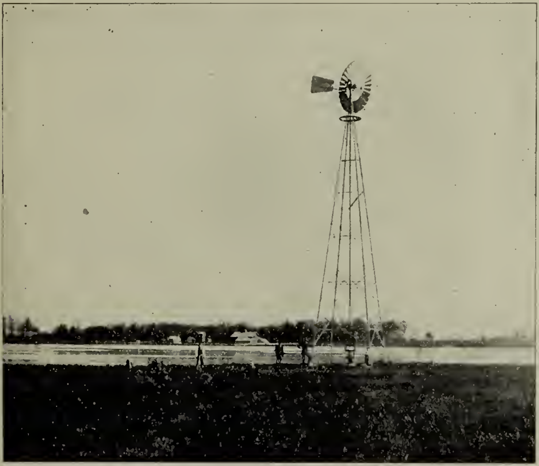


Fig. 6. View of extensive cranberry marsh when flooded in the spring. Sec. 24. Summerfield Township.

B. Relation of Soils to Vegetation.

§ 4. Fertility.

The bulk of all tissue found in the higher plants consists of carbon and water in chemical combination. The carbon is derived from the carbon dioxide of the atmosphere, being separated from its oxygen by the green coloring matter, known as chlorophyll, with the energy of sunlight. The water is derived from the soil mainly through the agency of roots. By combining chemically this carbon and water in certain proportion starch is made. From this starch, without the addition of any other kind of material, the plant produces sugar, gum, cellulose, lignin, oil, etc. The production of these substances, which so largely enter into the composition of all plants, constitutes no drain upon the soil. There are further needed, however, relatively small but important quantities of mineral substances, which can be derived only from the soil. These consist chiefly of potassium, sodium, calcium, magnesium, iron, phosphorus, silica and chlorine; all of which must enter the plant in chemical combination rather than as free elements. When the plant is burned this mineral matter constitutes the ash, while the carbon is united with oxygen again to form carbon dioxide and this with the water is restored to the atmosphere, to be used again in the same manner. When complete decay takes place the same changes occur but extend over a much longer period. It is self evident that a soil must be ready to supply, in available form, all mineral substances demanded for the complete development of those crops assigned to it. Table IX from the appendix of Johnson's "How Plants Grow," gives in convenient form analyses which were published some years ago by Prof. Emil Wolff, of the Royal Academy of Agriculture, Würtemburg. The various substances analyzed were in the condition in which they are handled by the farmer, that is, air-dried. The calculation of the amount of any mineral ingredient required for a given weight of each substance is very simple, since the figures represent the percentage composition. To illustrate, a ton of wheat would withdraw from the soil .55% of 2,000 lbs. or 11 lbs. of potash. A ton of red clover requires 1.95% of 2,000 lbs., or 39 lbs. of the same substance.

The failure of a soil to produce certain crops is not due necessarily to the absence of essential constituents in available form, but may be due to some physical disability. Some harmful ingredient may be present in disastrous amount, as an acid in the case of muck. Scarcely better advice can be offered the farmer now than was given sixty years ago by Bela Hubbard in the Second Report of the State Geologist (page 110); that he carry on experiments upon a small scale to determine the agricultural value of his various soils and inductively discover methods for improving them. It is now known that a mere chemical analysis cannot be implicitly relied upon to determine the character of the crop which the soil is capable of producing. Its fertility is in great measure dependent upon its texture, the mere size of its component particles. The finer the

TABLE IX.—PERCENTAGE COMPOSITION OF AIR-DRY FARM PRODUCTS. (WOLFF.)

Substance.	Water.	Ash.	Potash.	Soda.	Magnesia.	Lime.	Phosphoric acid.	Sulphuric acid.	Silica.	Chlorine.	Sulphur.
Wheat, grain	14.3	1.77	.55	.06	.22	.06	.82	.04	.03	....	.15
Wheat, straw	14.1	4.26	.49	.12	.11	.26	.23	.12	2.82	....	.16
Oats, grain	14.0	2.64	.42	.10	.18	.10	.55	.04	1.23	....	.17
Oats, straw	14.1	4.40	.97	.23	.18	.36	.18	.15	2.12	....	.17
Barley, grain	14.5	2.18	.48	.06	.18	.05	.72	.05	.59	....	.14
Barley, straw	14.0	4.39	.93	.20	.11	.33	.19	.16	2.36	....	.13
Rye, grain	14.9	1.73	54	.03	.19	.05	.82	.04	.03	....	.17
Rye, straw	15.4	4.07	.76	.13	.13	.31	.19	.08	2.37	....	.09
Corn, grain	13.6	1.23	.33	.02	.18	.03	.55	.01	.03	....	.12
Corn, stalks	14 0	4.72	1.66	.05	.26	.50	.38	.25	1.79	....	.39
Buckwheat, grains	14.1	.92	.21	.06	.12	.03	.44	.02	....	.02	....
Peas, seeds	13.8	2.42	.98	.09	.19	.12	.88	.08	.02	.06	.24
Peas, vines	14.3	4.92	1.07	.26	.38	1.86	.38	.28	.28	.30	.07
Beans, seeds	14.1	2.96	1.20	.04	.20	.15	1.16	.15	.04	.08	.23
Beans, plants	18.0	5.84	2.59	.22	.46	1.35	.41	.01	.31	.81	.22
Potatoes, tubers	75.0	.94	.56	.01	.04	.02	.18	.06	.02	.03	.02
Turnips	90.9	.75	.30	.08	.03	.08	.10	.11	.02	.03	.04
Sugar-beets	81.6	.80	.40	.08	.07	.05	.11	.04	.03	.02	....
Sugar-beet tops	89.7	1.80	.40	.30	.33	.36	.13	.14	.06	.10	....
Red clover hay	16.0	5.65	1.95	.09	.69	1.92	.56	.17	.15	.21	.21
White clover hay	16.0	6.03	1.06	.47	.60	1.94	.85	.53	.27	.19	.27

degree of comminution the greater is the total surface available for retaining moisture by what is known as capillary attraction. This moisture is spread out as a delicate film over the soil particles, so that the finer these particles are the greater is their combined surface, the more water are they capable of holding, and the more tenaciously is it retained for plant use. A cubic foot of compact limestone has 6 square feet of surface, or 864 square inches, but if sawed into 8 equal cubes, 6 inches upon a side, it possesses 1,728 square inches of surface. If cut into one inch cubes the total surface would be 10,368 square inches, or twelve times as great as the original surface of the cube. Similar treatment of each one inch cube would enormously increase the total surface, and the principle would be the same if the particles were of irregular shape, as is true in the case of soil. It has been estimated that a gram of soil contains from 2,000,000 to 15,000,000 individual granules, depending upon whether we consider a sandy or a clayey soil and the combined surface must be astonishingly great. An estimate made by Whitney gives a cubic foot of soil a surface of 50,000 square feet. If the soil is too loose and open, as in the case of sand, moisture is not properly conserved. Upon the other hand if the soil particles are too fine, as in a very compact clay, too much water is retained for the proper aeration of the roots and the perfect development of the plant. It must now be apparent why the loams and silts are the best soils, for it comes both from the standpoint of texture and the greater variety of material which they contain.

§ 5. Fruit culture.

The clay soils of Monroe county are rich in calcium carbonate owing to the prevalence of limestone in the county and to the north. With the favorable climatic conditions the grape grows luxuriantly in such soil and attains a high degree of richness. So abundant was this fruit along the river from Monroe to Dundee that the *Namet Cybi* of the Indians became *La Riviere aux Raisins* of the early French settlers. In a paper read before the Pioneer Society in June, 1883, Judge I. P. Christiancy thus describes the remarkable growth of the wild grape. The river, he says, was so called

> "from the immense quantities of wild grapes along its banks, which as late as 1843 and 1844 I saw growing on the Macon Reserve along this river and the Saline and Macon where the forest was still untouched, over the tops of the tallest forest trees; some of the vines being from six to eight inches through; which, after climbing to the tops of the trees, dropped branches to the ground, which again took root and made an inextricable mat of vines, such as I have never seen elsewhere except in the tropics."*

---

*Michigan Pioneer Collections, Vol. 6, 1883, pages 362-3.

With such a variety of soil and a favoring climate, conditions are found suitable for the growth of other fruit, besides the grape, but Monroe cannot be said to rank high in this regard, when it is compared with other counties of the state. The following table shows the number of bushels of fruit produced in the various townships during the season of 1898, as given in the Farm Statistics for 1898-9. Where no numbers are given the statistics are wanting.

TABLE X.—BUSHELS OF FRUIT PRODUCED IN 1898.

Townships.	Apples.	Peaches.	Pears.	Plums.	Cherries.	Strawberries.	Blackberries.	Raspberries.
Ash	1,039	141	116	4	16	15	....	8
Bedford	816	432	100	....	....	3,726	456	222
Berlin	1,264	30	150	66	....	....	....	....
Erie	4,078	5,065	1,682	5	190	1,489	181	811
Exeter	100	40	30	....	....	....	....	....
Frenchtown	225	170	25	30	....	150	100	275
Ida	1,417	....	33	5	....	80	68	25
La Salle	685	....	190	....	....	....	....	....
London	1,345	402	342	52	67	311	17	137
Milan	450	75	50	3	....	270	148	30
Monroe	947	1,460	741	27	12	289	127	525
Raisinville	1,203	521	321	53	27	85	4	51
Summerfield	405	480	75	100	....	....	....	....
Whiteford	2,026	427	1,156	92	279	477	41	103
Totals	16,000	9,243	5,011	437	591	6,892	1,142	2,187

An inspection of the table suggests that the best fruit producing townships are in the southern part of the county, including Erie, Bedford and Whiteford. This does not necessarily follow, however, although these townships have a slight climatic advantage over those farther north. It is probable that the nearness of the Toledo market stimulates the raising of fruit and that most of the other townships could make an equally good showing with an intelligent handling of the soils which nature has given them.

§ 6. Farm products.

In the production of the staple farm crops Monroe county ranks well both as to the number of bushels produced and the average yield per acre, the heavier soils being well adapted for the complete development of the cereals. Some localities are capable of

TABLE XI. MONROE COUNTY FARM PRODUCTS FOR 1898.

Township.	Soil.	Wheat.		Corn.		Oats.		Rye, bu.	Potatoes, bushels.	Beans, bu.	Clover seed. bu.	Hay, tons.
		Bushels.	Average.	Acres.	Bushels.*	Acres.	Bushels.					
Ash	Clay, sand	50, 072	20.16	2, 239	78, 805	1. 996	64. 947	162	10, 299	83	61	2, 944
Bedford	Sand	42, 113	21.50	2. 558	85, 642	1, 746	59. 892	2, 151	78, 896	177	....	2, 447
Berlin	Clay	23, 097	18.73	948	41. 127	1. 008	33, 304	100	2, 265	....	43	2, 047
Dundee	Clay, sand, silt	75, 000	18.75	5, 500	175. 000	5, 220	210. 000	8, 000	2. 000	....	....	8. 000
Erie	Clay, sand	56, 641	24.09	1, 733	78, 201	1, 273	50, 633	121	14, 352	13	207	3, 514
Exeter	Clay, sand	51. 936	18.84	2, 923	77. 363	2. 215	63. 430	....	10, 346	261	....	2, 755
Frenchtown	Clay, sand	61. 621	19.89	3. 085	110. 832	2. 714	84. 675	....	15, 157	....	81	3. 760
Ida	Sand, clay	58, 649	21.71	2. 797	101. 305	2. 076	70. 733	1, 626	42. 873	222	58	2. 525
La Salle	Clay, sand	60. 522	22.00	2. 300	121. 450	1. 872	59, 825	....	15. 703	18	163	2. 773
London	Sand	33, 656	19.94	1. 906	64. 136	1, 472	48, 256	2. 461	22. 029	493	26	2, 278
Milan	Clay	54. 159	22.34	2. 359	110. 600	1, 651	67. 715	....	9. 414	232	42	2. 361
Monroe	Clay, sand, silt	32. 923	22.04	1. 311	51. 425	1. 063	31. 988	50	8. 419	....	46	1. 641
Raisinville	Clay, sand, silt	87, 745	22.31	3, 829	110. 930	2. 914	96, 842	472	19. 633	35	108	3, 500
Summerfield	Sand	42. 890	21.67	2, 752	106. 245	1, 456	52. 174	1. 137	59, 930	14	10	2, 460
Whiteford	Clay, sand	59. 133	21.97	3. 479	135, 825	2. 370	92, 627	1. 546	60. 656	195	64	4. 120
Totals		793, 157	21.04	39. 719	1. 478. 886	31, 046	1. 089. 381	17. 826	372. 002	1. 743	912	47. 125

* Shelled.

yielding 30 to 40 bushels of wheat to the acre, but the average yield is but little over half this amount. For 1898 the average for the entire county was 21.04 bushels, Erie township leading with an average of 24.09 bushels to the acre. For 1897 the county average was 20.80 bushels which gave Monroe the rank of 6 when compared with the other 83 counties of the state. The county produces annually nearly a million bushels of wheat, over a million of oats and a million and a half of shelled corn. For the season of 1898 Table XI gives a summary of the yield by townships with the final total taken also from Farm Statistics of Michigan for 1898-9. The sand belts furnish desirable conditions for growing potatoes, beans and buckwheat. It would seem as though the sweet potatoes might also be grown with profit here, but the experiment has been tried only by a very few who report encouraging results. In Sec. 8 of Bedford township ¾ of an acre of heavy sand yielded 12 tons of Hubbard squash. The patches of muck, abundant in certain localities, are generally capable of producing good crops of cranberries. celery and peppermint. The analysis of three typical celery soils will show the composition required for such crops. There must not be over one per cent of iron sulphate present and the muck must not be "sour." ("Michigan Soils," Bulletin 99, Agricultural College.)

	Kalamazoo.	Grand Haven.	Newberry.
Sand and silicates	19.16	24.09	24.56
Alumina	1.40	1.71	2.21
Oxide of Iron	3.94	3.52	1.30
Lime	6 09	5.02	4.18
Magnesia	.81	.62	.75
Potash	.34	.20	.42
Soda	.38	.33	.40
Sulphuric acid	1.31	1.04	.67
Phosphoric acid	.88	.69	.46
Carbonic acid	1.95	1.05	1.10
Organic matter	63.76	61.73	63.75
Water	6.51	10.85	7.31

The rapid development of the beet-sugar industry in Michigan has created a demand for a new crop for which Monroe county soil and climate will be found well adapted. The ideal belt for growing the sugar-beet, so far as temperature alone is concerned, is determined by the summer isotherm of 70° F. This isotherm cuts diagonally across the county, from Toledo northwestward, and the entire county lies between the summer isotherms of 69° and 71°. The season opens early and the rainfall during the period of growth is all that is required. There is but one unfavorable feature relating to the climate and this is the amount of precipitation in September and October, which at Toledo is 2.38 and 2.32 inches respectively. The result of this precipitation at this time is to produce a second growth in the beet, which occasions a certain loss in percentage of sugar. Trial only will demonstrate whether the difficulty is sufficiently serious to involve considerable loss. There are thousands of acres in Monroe county which are well adapted to beet raising so far as soil is concerned. This should be a light loam with a clay subsoil, level but well drained, either naturally or artificially. Thin soils with hard clay subsoils do not allow the tap roots proper development. Wiley, the American authority upon the subject, says, "In general any soil which will give good crops of the cereals and other farm products will produce good sugar-beets." According to the Land Commissioner French, during the season of 1898 Monroe county produced 215½ acres of beets. Previous experiments have demonstrated that the beets are of good quality. Estimates for the state place the amount received for each acre at $53, half of which represents profit. The following paragraph from "Progress of the Beet-Sugar Industry for 1898," by C. F. Saylor, is full of encouragement:

> "Thirty-four samples were received from the State of Michigan, showing a fine average weight, a satisfactory content of sugar, and a high purity. The results of the experimental work in Michigan last year were of such an encouraging nature as to justify the establishment of a beet-sugar factory at Bay City. Other factories are now building, and Michigan gives promise of becoming a strong rival to California in beet-sugar production. Evidently all parts of the State are capable of producing high-grade beets, and the climatic and soil conditions are extremely favorable. The data of this and previous years show beyond question that Michigan is one of the best states of the Union for sugar-beet culture." (Page 151.)

§ 7. Forest growth.

The character and distribution of the timber is determined directly by the nature and distribution of the soils already described. Upon the heavy clay are found oak, ash, elm, beech, hickory, black-walnut, bass, maple, whitewood, and along the water courses, sycamore. A singular belt of hickory, about one mile wide by two to three in length, extended originally in a northeast and southwest direction through Secs. 5, 6, 7 and 8 of Milan township. This region furnishes also most of the beech found in the county. The regions of heaviest sand have but a scanty growth of timber, consisting mostly of yellow, white and burr oak which form the so called "oak openings." In the swampy regions "popple" and tamarack are abundant. North of the Raisin the chestnut is common on the sand belts and extends northward into Wayne county.

The farmers uniformly report this tree as absent south of the river upon the same sand areas, over which it is abundant to the north. It appears that the Raisin has thus far constituted a barrier to the southern progress of this tree. In a preliminary survey of the flora of southeastern Michigan, Prof. C. F. Wheeler of the Agricultural College, in 1890, noted the following 55 trees:

Acer dasycarpum	Silver maple.
A. rubrum	Red maple.
A. saccharinum	Sugar maple.
A. saccharinum, var. nigrum	Black maple.
Aesculus glabra	Ohio buckeye.
Asimina triloba	Papaw.
Amelanchier Canadensis	Shad-bush.
Betula papyracea	Paper birch.
Carpinus Americana	Ironwood.
Carya alba	Shagbark hickory.
C. amara	Bitternut.
C. porcina	Pignut.
C. sulcata	Big shell bark hickory.
Castanea sativa, var. Americana	Chestnut.
Celtis occidentalis	Hackberry.
Cercis Canadensis	Red bud.
Cornus florida	Dogwood.
Cratœgus coccinea	Red haw.
C. coccinea, var. mollis	Red haw.
C. crus-galli	Cockspur thorn.
C. tomentosa	Black thorn.
Fagus ferruginea	Beech.
Fraxinus Americana	White ash.
F. sambucifolia	Black ash.
Gleditschia triacanthos	Honey locust.
Hamamelis Virginiana	Witch hazel.
Juglans cinerea	Butternut.
J. nigra	Walnut.
Liriodendron tulipifera	Whitewood.
Morus rubra	Red mulberry.
Negundo aceroides	Box elder.
Nysa multiflora	Sour gum.
Ostrya Virginica	Water beech.
Platanus occidentalis	Sycamore.
Populus balsamifera	Balsam poplar.
P. grandidentata	Large toothed aspen.
P. monilifera	Cottonwood.
P. tremuloides	Aspen.
Prunus Americana	Wild plum.
P. serotina	Wild black cherry.
P. Virginiana	Choke cherry.
Quercus alba	White oak.
Q. bicolor	Swamp white oak.
Q. coccinea var. tinctoria	Black oak.
Q. macrocarpa	Burr oak.
Q. palustris	Pin oak.
Q. rubra	Red oak.
Rhus glabra	Smooth sumach.
Salix amygdaloides	Western black willow.
S. nigra	Black willow.
Sassafras officinale	Sassafras.
Tilia Americana	Basswood.
Ulmus Americana	White elm.
U. fulva	Slippery elm.
U. racemosa	Corky white elm.

C. *Amelioration of Soils.*

§ 8. Importance of subject.

Until the unwelcome truth is forced upon their attention probably most farmers look upon their land as an inexhaustible source of wealth, requiring only so much sunshine and moisture and so many hours of physical labor. Their farms to them are like the mythical hen which laid golden eggs without having to be fed upon bullion. In a state of nature the materials drawn from the soil by vegetation, are sooner or later returned to it, with a high rate of interest in the form of organic matter. It is impossible for this to occur when the land is under cultivation, otherwise there would be no advantage in such cultivation. A drain upon the soil is at once started, the nature and amount of which depends upon the character of the crops harvested. Every load of grain marketed, every animal fattened upon the farm means a certain reduction in its resources. It is not sufficient to return the straw and manure in order to make good the loss. This could be done only by again scattering the grain over the fields and restoring to the soil the carcasses of the animals fattened at its expense. Most of the older farmers will recall that the shocks of wheat do not stand as closely now as in former years. It is folly for the farmer, and especially for one who has his fortune still to wrest from his land, to allow his soil to become depleted and barren as has happened in many sections of New England and Europe. Left entirely to itself, in the course of time, the fertility of the land is restored by natural agencies, which it may be well to briefly consider since they will suggest means of artificial amelioration. Some of these agencies have worked with extreme slowness and seem trival, but operating through a long period, their effects have been great and to their action is due the happy, prosperous condition today of many Monroe county homes.

§ 9. Natural amelioration.

(a). Inorganic agencies. The drifting of loose sand by the wind over adjoining clay areas, although frequently disastrous, has produced belts of loam in the county which are better suited to most crops than either the sand or the clay alone. A similar action has taken place about the knolls and ridges through the agency of surface water, the sand being washed down and spread over the adjoining clay areas. Under cultivation finely pulverized clays are frequently taken as dust into the air and spread over adjoining sand belts, giving them more body and supplying, to a greater or less extent, the variety of materials which they need in order to support the staple crops. These clay particles may be carried beneath the surface by percolating water and become a permanent acquisition of the sand. Rain brings to the soil yearly small quantities of nitrogen in ammonia and nitric acid. From observations extending over a number of years at various stations in Europe it is estimated that the average amount of these two nitrogen compounds per acre is 10.23 lbs. a year, with a range from 1.86 lbs. to 20.91 lbs. This is estimated by King as sufficient to supply the nitrogen required for two bushels of wheat.* Similar observations show that sulphuric acid is also present in rain water, but in smaller quantities. For a rainfall about equal to that of Monroe county the estimated amount is 2¼ lbs. to the acre for each year. Springs may locally add desirable ingredients to the soil, although too great quantities are generally deposited while the spring is active. In case the spring dries up the excess may be removed through the agency of rainwater and the character of the original soil more or less improved.

If one examines a pile of field stone many will be found, which although firm and solid within, are covered with a soft mealy crust, soft enough to be easily removed with the finger-nail. This is particularly true of rocks rich in plagioclase feldspar, hornblende and mica, less so for those containing much orthoclase feldspar and not at all so for the quartzites. This phenomenon is known as a "weathering" and results from the absorption of moisture by the minerals and their chemical disintegration. Both soluble and insoluble compounds result from this action, the former being taken into solution by the rainwater and carried to the streams, while the latter material is added to the soil. Boulders of considerable size may sometimes be found in which this destructive change extends to the center, so that they readily crumble at the touch or may easily be pulled to pieces with the fingers. This decay of the crystalline rocks adds to the soil silica, alumina, calcium carbonate and valuable quantities of soda and potash. When iron is present, even in small quantity, its oxidation and hydration takes place, staining the weathered material brown to yellow. The lasting qualities of glacial soils are due, in part, to this continuous enrichment which they receive from the rock fragments contained. Shaler has attributed the ranker growth of vegetation about surface boulders to this action.† Since this phenomenon may be seen about objects incapable of yielding nutriment to the soil it may be questioned whether the effect is not due mainly to the conservation of moisture and heat by the object. The disintegration of rock masses is greatly facilitated in temperate regions by alternate freezing and thawing of the water which collects in its pores and crevices. It has been determined that even solid granite will absorb .4 of a pound of water for 100 pounds of the rock. Upon freezing this water exerts an enormous disruptive force, producing crevices where none existed and enlarging others already formed. The great Ida boulder shown in Fig. 1 furnishes an illustration at its smaller extremity, where a large fragment has been flaked off in the way described. These crevices allow the destructive atmospheric agencies to operate over a larger and larger surface, thus greatly facilitating complete disintegration. Cleopatra's Needle, which safely withstood centuries of Egyptian climate, has suffered severely from a quarter-century of New York's changes and, in order to be preserved, must be housed as are other exotics.

---

*The Soil, pp. 119-120.

†Origin and Nature of Soils. Twelfth Annual Rep., U. S. Geol. Sur., part I, pages 237 and 288.

(b). Organic agencies. Plant and animal agencies have a very important share in the natural improvement of soils already formed, or forming, operating in a variety of ways. In the case of the Ida boulder above referred to, the crevice which has been formed by the frost is now filled with soil in which smaller plants grow every season. In the course of time the wind, or a bird, will leave there the seed of some tree or shrub, which in its growth may completely rend the rock asunder. The accumulation of leaves in such a place, combined with growth in place of lichens and mosses, will furnish carbon dioxide gas and organic acids after their decay. These compounds added to the rainwater will greatly increase its power to dissolve substances from the rocks. Even the refractory quartz yields readily to its power. Hayes has recently cited instances of the solution of pure quartz through the agency of humic acids.* and gives Thenard as authority for the statement that simple humic acid will dissolve .8% of silica. After absorbing nitrogen from the air, however, and becoming azohumic acid it is capable of combining with 7 to 24% of silica, depending upon the quantity of nitrogen used. Compounds are formed which are readily soluble in alkaline carbonate solutions. Where conditions are favorable for the growth of bacteria, compounds may be formed which have a similar effect upon rock masses, thus rendering available to plants a larger quantity of mineral matter. The rootlets of the coarser plants and particularly those of shrubs and trees penetrate the subsoil to considerable depths, forming channels through which surface water and atmospheric gases may enter, thus extending downward the action of these agencies. The overturning of trees by tornadoes frequently results in a mixing of soil and subsoil on account of the quantities of earth adhering to the roots. The effect, however, is just as liable to be disastrous as beneficial. Not only indirectly, as just pointed out, but directly through its partial decay, is the soil enriched through various forms of vegetation. The mineral substances required for plant growth are derived from the soil and returned again after the decay or combustion of the material. The carbon, however, which is the basis of nearly all plant products and some nitrogen, in certain cases, are drawn directly from the air, as explained in § 4 of this chapter. The incorporation of vegetation into the soil thus adds to it materials which it did not originally possess and to this extent it is enriched. Not only plant food is thus introduced but the undecayed carbonaceous matter renders the compact soils more porous, less wet and heavy, while the lighter soils are better enabled to retain their moisture. The dark color imparted to the soil gives it the power to absorb more of the sun's heat.

---

*Bull. Geol. Soc. of Amer., Vol. 8, 1897, pp. 218-219.

In this work of soil amelioration the plants are assisted to a great extent by animals. Charles Darwin in his book entitled "The Formation of Vegetable Mould," first called attention to the important effect of earthworms in working over and loosening up the soil. They, however, work mostly in soil that is already rich and hence needs their help least. Here they are frequently present in surprising numbers but almost or quite absent from heavy clay and light sand. They have the habit of passing through their long alimentary tracts, as they burrow, quantities of earth upon which their digestive juices act. The soil particles are triturated, softened, partially dissolved and finally ejected upon the surface in relatively large quantities. Penetrating to a depth of six to eight feet they bring to the surface the subsoil, thus mixing and deepening the layer of true soil. Darwin estimated from his observations in England that every five years the equivalent of one inch of soil is thus worked over by these lowly creatures (page 171). Their burrows allow atmospheric gases and surface water to reach the lower strata. Further, the earthworm draws into its burrow at night, to a depth of two to three inches, quantities of leaves. Enlargements in its burrow are lined with small seeds and pebbles. The vegetable matter thus introduced in part decays and enriches the soil. When this action is continued for one or more centuries its importance can scarcely be over-estimated. Next in importance to the earthworm may be mentioned in this connection the ant. The former prefers a damp soil while the latter selects one somewhat drier. In excavating their galleries they bring fine particles to the surface, sometimes from a considerable depth, thus securing the desirable mixing of soil and subsoil. Shaler has found the soils of certain fields in Massachusetts entirely altered through the agency of ants, and estimates that one-fifth of an inch of material is annually brought to the surface (page 278). Both animal and vegetable matter is introduced into the soil through their agency and their burrows secure more or less aeration for it. In tropical regions the work of ants is far more extensive, immense quantities of earth being brought to the surface. Branner has very recently described a region in Brazil the surface of which is nearly covered with their mounds, varying in height from 3 to 14 feet and in diameter from 10 to 30 feet.* Their channels were observed to extend to a depth of 13 feet below the surface, and through them surface waters are introduced, hastening the decay of the underlying rock. The larvæ of many forms of insects burrow into the soil and bring about some of the above results, but to a less extent.

In the southern part of Summerfield township Mr. Ezra Lockwood informed the writer that his sandy soil had been very materially improved through the agency of crayfish. These creatures construct long subterranean passages, about an inch in diameter and many feet in length, finally terminating at the surface. Over this entrance they frequently build up a chimney of clay for which it is difficult to assign any particular use. Standing several inches above the low flats they look as though they might be intended to exclude surface water from the burrow, but the crayfish would scarcely object to such water. If it left the mouth of its burrow, in case of surprise the crayfish would have difficulty in retreating, and quite probably the clay which it is desirable to remove in enlarging the entrance is thus heaped up in order to avoid leaving the burrow. The beneficial result noted comes from the mixing of this clay subsoil with the surface sand. In certain places these burrows assist in draining a marshy area and rendering it more tillable. A large number of burrowing animals exercise a similar effect, slight in any particular case but important in the aggregate. There may be mentioned mice, gophers, wood-chucks, rabbits, muskrats, moles, birds, etc., which excavate burrows, mix the soil and subsoil, and introduce beneath the surface more or less organic matter. In all these cases cited the animal forms themselves eventually die and their remains are added to the soil. Valuable mineral and organic compounds are thus introduced which are worked over into plant tissue and finally again into animal. If the bodies still remained of all animal life that has died upon a given area since the close of the Glacial Epoch it is quite probable that the ground would be seriously encumbered with their carcasses.

---

*Jour. of Geol., Vol. VIII, No. 2, 1900, pp. 151 to 153.

§ 10. Artificial amelioration.

Nature offers many suggestions to the farmer whereby he may improve the character of his soil which is gradually and surely being impoverished. He may simply imitate the least expensive and most effective of her processes. One of these is the simple mechanical mixing of clay, sand and muck in sufficient proportions to form a loose, dark loam. In many regions this may be done by deep plowing, these different soils frequently overlying one another in close proximity near the surface. Many fields on the outskirts of the Forest and Grassmere beaches contain surface patches of sand and muck surrounded by clay. By means of a cart and scoop in the course of a few seasons these could be mixed and a valuable soil produced. Waiting for nature to accomplish this will seriously postpone the resultant harvest, as she is too dilatory in her methods. What would be supplied to the soil in the course of years through the disintegration of rock masses must be furnished more lavishly when the soil is under cultivation. An inspection of Table IX, § 4, of this chapter, shows that plants draw from the soil potash, soda, magnesia, lime, phosphorus, sulphur, chlorine and silica. Nitrogen in general must also be so obtained, although exceptionally it may be secured from the atmosphere in the way described below. Iron is also a necessary soil ingredient for the complete development of crops, but this along with the chlorine and silica is sufficiently abundant in all soils. Marl, ground limestone and "plaster" will cheaply supply lime, magnesia and sulphur. The earlier geological surveys strongly called attention to the value and availability of marl as a fertilizer. The loss which the soil sustains in potash, soda, phosphorus and nitrogen is more difficult to make good, involving the use of manures and commercial fertilizers. Upon application the State Agricultural College will gladly supply to all their analyses of the fertilizers now upon the market, from which there may be obtained an idea of their relative value for certain soils and crops.

Patches of muck land, which might support crops of cranberries, celery and peppermint are frequently found barren because of an excess of free acid. Such muck smells sour and will turn blue litmus paper to a red color. This condition may be remedied by drainage, loosening of the muck so as to well expose it to the weather, and by neutralizing the acid with marl or wood ashes. In his Report of 1861 (page 194), Dr. Winchell discusses this subject in language well worth reprinting in this connection.

> "Nature has placed it (the material for overcoming the acidity of the muck) in the form of marl, in immediate juxtaposition with the peat which needs its agency. Indeed the farmer can in many cases load his cart with the mixed deposits without even moving his team from their tracks. I hardly know a more striking adaptation of natural means for the accomplishment of a necessary object. The porous nature of our soils suffers their soluble constituents to be carried away to the lower levels where peat and marl are accumulating, and where the growths of ages unknown, have been adding a thousand fold to the nutritive elements brought down from the soils of the contiguous hill slopes. These depositories of agricultural force, a good economy will not fail to appreciate and apply to the recuperation of declining wheat lands."

A practical method of increasing the fertility of soil, through the addition of nitrogen, has long been known to the farmer although few can explain the steps in the process. The procedure is purely an empirical one. If a plant of clover be pulled up and the soil washed from its roots there will be found upon them small irregular lumps, "tubercles." If one of the tubercles be picked to pieces upon a strip of glass and examined with a high power microscope there will be found minute stick like bodies in enormous numbers. These are one-celled plant organisms known as "bacteria" and in some way, as yet unknown, they enable the clover plant to appropriate the free nitrogen of the air. Beans, peas, lupine, and leguminous plants in general are similarly aided by various species of these nitrifying bacteria. Other plants not so assisted are surrounded by a great atmosphere of this nitrogen of which they are unable to appropriate an atom. They may be compared to the wrecked mariner upon a desert island, who famishes for lack of water although surrounded by the great ocean. In addition to the mineral matter taken from the soil and the carbon from the atmosphere, the crop of clover stores up nitrogen derived from the air. The plowing under of such a crop then adds to the soil valuable plant food which it did not possess. If a soil is too poor to produce clover suitable fertilizer may be applied first and then the field sown with clover, preferably one of the coarser varieties. The nitrogen of the soil is in part free and in part in the compounds ammonia, nitrous and nitric acid, nitrates of sodium, calcium, etc. The ammonia which is a valuable ingredient of barn yard manures, is converted into nitrous acid through the agency of bacteria and this is changed into nitric acid, in which form it may be utilized by plants. If the soil is too wet some of these compounds are broken up, the nitrogen returned to the air and the soil to this extent impoverished.

CHAPTER VIII.

ECONOMIC PRODUCTS.

§ 1. Building materials.

A detailed description of the geological features of the various quarries of the county and layers exposed has been given in Chapter IV. At nearly all these localities stone for curbing and rough masonry may be obtained in unlimited quantities. Along the anticlinal ridge in the eastern part of the county the rock is shattered in places and its value much diminished for construction work. The lower layers in the Navarre quarries on Plum Creek are, however, heavily bedded and masses two and a half feet in thickness are being removed. In all the quarries in southeastern Michigan it is found that the surface layers are shattered and thin bedded, probably from the enormous pressure of the ice sheet and subsequent action of the frost. The Monroe beds which lie between the Sylvania sandstone and the Dundee limestone furnish the best building stone in the county. About Ottawa Lake, however, the layers are too thin bedded and their color is not uniform, so that they are desirable only for rough work. Northeastward these beds improve in quality. At the Little Sink, Lulu and Ida quarries good building stone, but no massive blocks are obtained. The blue streaked dolomite previously described as occurring at the Lulu quarry has a thickness of 20 inches, is of a fine texture and would probably take a good polish. Upon exposure to weather the blue color would rust and the rock shows a tendency to check, but for indoor work it might prove of value.

The most massive blocks for building, curbing and flagging are obtained at Woolmith quarry (Chapter IV, § 4), from a very thick bed of silicious dolomite of a light brown color, sold in the market as a "sandstone." Plate II gives a view of some of the blocks of this bed that may be obtained by the use of steam channelers. Masses of almost any desired size may be secured and sawed into shape. Thin dark seams detract somewhat from its value for fronts. According to the Company its crushing strength as determined by Gen. Q. A. Gilmore and Col. Herman Kallman, of the U. S. Engineers' Office in Detroit, is 13,800 pounds per cubic inch. Much of this stone has been used in Detroit during the past five years. The Macon and Dundee quarries furnish some heavy blocks of very pure limestone two to three feet thick, suitable for bridge work. The rock is impregnated with oil which would render it objectionable for many uses. The oil near the surface is lost upon standing, after which the rock grows lighter in color and the oil still contained within would contribute to the preservation of the stone. The sills and cappings of the old court house at Monroe were of this stone and well stood the test of years. About 200 cords of this stone are taken out yearly from each of the two quarries.

§ 2. Quick lime.

Since the early occupation of this region by white settlers lime to supply the local demand has been burned wherever the rock was available. Small openings were made into the upper layers and in the vicinity of outcrops, loose fragments were collected from the surface. The kilns were constructed, whenever convenient, along hillsides so that the rock could be dumped in from above. Their remains are frequently met with along the line of the "Stony ridge" from Ottawa Lake to Stony Point. As early as 1838, according to Hubbard, three kilns were in operation on Plum Creek, burning 900 to 1,000 bushels annually, five at Ottawa Lake, producing 2,500 bushels, and eight kilns upon the Macon, yielding 6,000 to 8,000 bushels annually. At the time of the Winchell Survey in 1859 and 1860 the Macon kilns were turning out about 10,000 bushels annually, and those upon Plum Creek a much greater amount. The chief business, however, was carried on at Raisinville (Grape) where 13 kilns were in operation, each with a capacity of 8,540 bushels. Dr. Winchell estimated that about 295,000 bushels were being produced annually in the county with a value of $36,875. At present writing lime is being burned at but three points in the county. Upon Plum Creek a small kiln of a capacity of 500 bushels is operated by Hugh Gaffny but only enough lime is produced to supply the Gas Company, 1,000 bushels in 1899 and 3,000 bushels in 1898. The rock used is the local dolomite, giving a slow slacking lime. The increasing cost of fuel has seriously interfered with the business. With wood as fuel the time required for burning was 72 hours, but by using alternate layers of fine coal and dolomite this time is reduced to 50 hours. At

Grape S. A. Kring has been operating the quarry up to a recent date owned by Robinson and Taylor, of Detroit. The rock burned is a dolomite which showed upon analysis of magnesium carbonate 45.01%, calcium carbonate 51.69% and of silica 3.45%.* Small quantities of iron, alumina and gypsum occur also. This yields a lime which slakes slowly, does not develop much heat, increases relatively but little in volume and will not take as much sand. This type of lime sets slowly and is preferred by many builders. Mr. Kring operates a continuous, double kiln from which every eight hours 75 bushels of lime may be withdrawn. The industry is continued for eight months in the year with eight hands and three teams, by which the product is drawn to Maybee, Ida and Monroe for shipment. For the past two seasons there have been burned here 35,000 bushels of lime annually, which has retailed at the kiln at 18 to 20 cents a bushel and in car load lots sold for 14 or 15 cents.

An entirely different type of lime is that manufactured at the Macon quarry from the pure limestone. This is of a purer white color, slakes very rapidly, developing much heat and increasing greatly in volume. It is capable of binding together much sand and is consequently said to be "strong." Owing to its "lively" character it is difficult to confine it in barrels. There are four kilns here, but two of which are in repair. These yielded 6,000 bushels in 1898 and 1,000 in 1899. Ordinarily only the two upper beds are used, of which the upper yields the whiter lime, (Chapter IV, § 1). The third bed yields a "livelier" lime than the upper two. The conversion of such limestone ($CaCO_3$) into lime (CaO) is accomplished by driving off the carbon dioxide (CO_2) at a temperature of about 824° F. The markets for the Macon lime are mainly local, but it is regularly supplied to the Southern Chemical Company, manufacturers of wood alcohol at Yuma, Michigan. Considerable lime was at one time shipped to Ann Arbor and Detroit but lack of shipping facilities prevented competition with more favored localities. The Detroit and Lima Northern now passes within a few rods of the quarry and these facilities are in consequence much improved.

Lime has been burned at Woolmith and at Ottawa Lake but the quality at each place was found unsatisfactory. Excellent facilities for manufacturing and shipping a promising variety of magnesian, or dolomitic lime, are found at the Ida quarry. A large double kiln of the continuous type stands upon the edge of the quarry and but a few feet from the Adrian-Monroe branch of the Lake Shore railroad. Lime was burned here up to the time of the last financial depression and has not been since resumed. The best grade is made from the upper six feet of the second bed (Chapter IV § 6). It slakes slowly but is said to be strong for this variety of lime. It hardens into a substance more nearly resembling cement than mortar, becomes fully as hard as limestone itself and well resists the weather. In a private letter from Homer Wilcox, a Jackson dealer in lime, cements, etc., the following estimate is given of this lime.

---

*Some of these dolomites might be suitable for basic furnace linings. L.

> "The ordinary quick lime manufactured at Ida is not liked as well as some other limes because it slakes so slowly. When used, however, it furnishes a stronger bond and though slowly setting becomes ultimately harder than the quicklime from Ohio, around Fremont and Genoa, or the darker quicklime from the Marblehead territory. * * * Burned moderately it makes a white, slow-slaking, hard setting lime and though it works cool and sets slowly, when it does set is very strong and resists action of water almost equal to hydraulic cement." (Jan. 28th, 1897.)

From figures furnished to the U. S. Geological Survey at Washington the total value of the lime for this county was $4,520 in 1897, $5,163 in 1896 and $6,675 in 1899. These figures appear to be somewhat below the actual amount produced. It is certain that the amount of this product could be indefinitely increased and of each of the three varieties described.

§ 3. Soda ash limestone.

For the manufacture of sodium bi-carbonate ($Na\ H\ CO_3$) known ordinarily as "soda ash" now being produced in great quantity along the Detroit River, a high grade limestone is required. This should contain from 95 to 99% of calcium carbonate with only small percentages of silica and iron. The carbon dioxide of the stone is driven off by heat as in the ordinary manufacture of lime and is made to combine with the sodium of the salt made use of in the manufacture of the ash. At present most of the rock is supplied by the extensive Sibley quarry near Trenton from their remarkable "9-foot bed." The only formation in Monroe county capable of yielding stone of requisite purity is the Dundee (See Plate 1) and the only accessible locality is on the Macon, northeast of Dundee. It is probable that here are found the identical beds of the Sibley quarry, reduced in thickness and somewhat altered in character, but still exceptionally pure, (See descriptions and analyses Chapter IV, § 1). The limestone here is impregnated with oil which would render it objectionable for the manufacture of soda, but it would seem as though this might be either burned from the stone at a lower temperature than that at which the gas would escape or else washed from the gas in case the oil and gas were driven off together. In the Christiancy quarry the disposition of the water is a serious matter on account of the nearness of the Macon. In describing the quarry it was pointed out that this difficulty would become relatively less as the quarry was deepened and broadened. Another site for a quarry in which water would probably cause still less trouble may be found about 80 rods to the northwest upon land formerly belonging to James Brown, now owned by B. E. Bullock, of Toledo. The rock is said to come to within five to six feet of the surface which would not mean an excessive amount of stripping considering the thickness of the strata that could be worked for one purpose or another.

§ 4. Beet sugar limestone.

The wonderful development of the beet sugar industry in Michigan has still further stimulated the search for higher grade limestone. The specifications required are essentially the same as for the stone used in the manufacture of soda ash. If found at all within Monroe county it must be at the localities mentioned above, which fortunately are surrounded by favorable agricultural regions for the growth of the beets. The stone is burned in kilns and both the carbon dioxide gas which escapes and the lime left behind are utilized in the manufacture of the sugar. The limestone should be compact and hard and not in fine pieces, otherwise it will "bridge" in the kiln and give trouble. For this reason marl cannot be made use of for this purpose. The percentage of silica, silicates and alumina needs to be low, since these will cause fusion in the kilns, the compounds adhering to the sides and "bridging." Magnesia and gypsum are not objectionable in the kilns but they interfere with the filtering and evaporation of the juice. It is said that magnesia may be tolerated up to three per cent. One per cent of moisture in the stone is considered desirable but as much as five per cent is objectionable since it interferes with the burning. A good quality of coke is recommended as fuel rather than coal which may introduce impurities into the lime and gas. The table of analyses opposite is taken from Special Report on the Beet-Sugar Industry in the United States for 1897.

Numbers 1, 2 and 3 were found to be satisfactory, while 4, 5 and 6 are excellent. The analyses of the Macon limestone make a very good showing when compared with these, but it is not to be expected that all the beds will prove equally suitable. The oil will prove an objectionable ingredient unless it can be disposed of in the way

TABLE XII.—COMPOSITION OF LIMESTONE FOUND SUITABLE FOR BEET-SUGAR MANUFACTURE.

Ingredients.	1.	2.	3.	4.	5.	6.
Moisture	4.17	6.25	5.16	.52	1.21	.11
Sand, clay and insoluble matter	3.07	3.17	2.25	2.85	.55	.27
Organic matter	.97	1.12	.86	.30	.41	.15
Soluble silica	.98	.64	.56	.06	.20	.03
Oxides of iron and alumina	.19	.15	.20	.32	.23	....
Calcium carbonate	88.65	87.93	90.03	93.80	96.58	99.10
Magnesium carbonate	.95	.50	.45	1.81	.50	....
Sodium and potassium (Na_2O, K_2O)	.01	....	....	....	....	....
Undetermined	1.00	.24	.39	.34	.32	.34

suggested, or in some better manner. In the manufacture of the sugar the juice of the beet is treated with the lime either in powdered form or as "milk of lime." This lime unites mechanically and chemically with the impurities of the juice after which the carbon dioxide gas, driven from the limestone by heat, is allowed to bubble through the limed juice. A recombination takes place forming the calcium carbonate anew as a flaky precipitate which carries the impurities to the bottom. This calcium carbonate is separated from the juice containing the sugar by passing the latter through a cloth filter. This precipitate has value as a fertilizer and the farmer may bring his beets to the factory and take back a load of this material for enriching his soil. Lime is sometimes further used in recovering from the waste substance known as the "molasses" its final content of sugar. This sugar may equal 15 to 20% of that contained in the beet and is made to unite with lime forming tricalcium saccharate, which may be filtered out. In some of the European factories this sugar is recovered by the use of strontia, derived from the mineral strontianite, a mineral which occurs at several localities in Monroe county, but so far as we yet know only in limited quantities. The strontium is again carefully recovered in the form of the hydrate and after the process is started, simply the loss has to be made good. This loss as calculated by Prof. Wiley, in terms of strontianite would equal 6.25% of the weight of the molasses treated, rather more than the county could supply unless richer deposits are uncovered. For a factory using 300 tons of beets daily it is estimated that from 35 to 40 tons of limestone would be required daily, the exact amount depending upon the purity of the stone.

§ 5. Cement materials.

A widespread and deep seated impression has prevailed for a long time in and about the county that the dolomites of the Monroe beds possess hydraulic properties; that they are capable of producing a cement capable of hardening under water. This has resulted very probably because of their equivalency with the noted "waterlime" series of New York. In his report for 1840 Hubbard says that experiments upon the rock about Monroe had already demonstrated its value for such purpose. Winchell in 1861 suggests that further tests be made upon the rock with a view to determining just what hydraulic properties it does possess. Some little experimentation has been carried on by private parties but no complete or conclusive tests have been yet applied. Edward Vorster, formerly of Monroe, now of New York City, conducted some experiments upon the Monroe stone which proved unsatisfactory, he thought because of the absence of sufficient soluble silica and the presence of too much magnesia. Magnesia, however, is perfectly hydraulic and when properly calcined will set under water and form a stony mass. Homer Wilcox, of Jackson, in a letter quoted above in § 2, makes the following statement concerning his tests upon the Ida dolomite:

> "From a series of experiments with rock from quarries one mile west of Ida Station, Monroe county, Michigan, I did not find the burned and ground rock a true hydraulic cement and yet it possessed properties different from any other rock I found in Monroe county, and I secured samples from, I think, all the quarries in that county. Ida limerock burned moderately hard, made a slow-slaking, slow setting lime when used as quicklime, but the same stone burned very hard lessened in bulk, became heavy and would not slake; but when ground into a flour and mixed with water set slower than the ordinary cements of the country (Akron or Louisville), and became ultimately harder than either Akron or Buffalo. I was, however, unable to calcine the rock hard enough in ordinary kilns to insure this result."

Hydraulic properties of perhaps a high order of excellence are suggested by these experiments. With specially constructed kilns and skilled labor in charge the rock might be made to produce a good quality of hydraulic cement.

The requirements for an hydraulic cement rock, according to Lord, are a limestone, magnesian or not, having intimately mixed with it 15 to 35 % of clay and a little potash or soda. Sand should not be present in the form of grit and the rock should dissolve in hot acid giving much muddy residue. Mr. Edward D. Boyer the Superintendent of the Hercules Cement Co. of Catasauqua, Pa., has kindly supplied the following average analysis of their rock, which, he says, is practically the same for the entire now famous Lehigh region.

Calcium carbonate	69.375
Silica	14.280
Alumina	9.000
Iron	2.810
Magnesium carbonate	2.353
Potash salts, moisture	2.182
	100.000

A table of American cement rocks was published in Vol. VI of the Ohio Geological Survey which may be of value in this connection for reference. The proportions of the various constituents are seen to vary greatly. These rocks are burned with a bright red heat in suitable furnaces and then ground in mills to an impalpable powder.

TABLE XII.—COMPOSITION OF AMERICAN CEMENT ROCKS.

Locality.	Calcium carbonate.	Magnesium carbonate.	Silica.	Alumina.	Iron oxide.	Alkali.
Ulster Co., New York	30 72	35.10	19.64	7.52	2.38	4.10
Cumberland, Maryland	41.80	8.60	24.74	16.74	6.30	6.18
New Lisbon, Ohio	69.00	3.40	15.65	6.80	2.50	....
La Salle, Illinois	42.25	31.98	....	22.18	....	....
Bellaire, Ohio	46.52	26.40	16.41	5.44	3.38	....

The composition of the rock has to be carefully watched in order to determine the amount of burning required and the grinding needs the same careful supervision. So far as analyses have been made of the Monroe rocks there are none of them which show a composition which would promise much in this direction. There is too much silica of the insoluble variety in many of the beds and in none of them does there seem to be sufficient alumina.

In the manufacture of Portland cement the proper proportions of clay and calcium carbonate are artifically united and burned at a temperature of 2,900° F. During this burning calcium silicate, and calcium aluminate are formed (the former below 1300° the latter above), which upon being ground and then wet, become hydrated, harden even out of contact with air and form insoluble masses. These cements do not slake as does lime and do not require any carbon dioxide gas from the air in order to harden. The celebrated English cements are made from the chalk beds and clay dug from the ancient bed of the Thames and Medway rivers. Analyses of these cements show the following range in composition, according to Heath.[*]

Lime	58 to 66%
Silica	20 to 26%
Alumina	2.5 to 10%
Potash	1 to 3%
Soda	0 to 2%

A mixture that ordinarily suffices to secure the proper composition is 72 to 77% of calcium carbonate and 23 to 28% of clay. The carbonate may be in the form of limestone or of marl and should be quite free from magnesia and sand. The clay should be of an even grade and free from grit. When rubbed between the fingers it should have a smooth greasy feel and should not stain the fingers. Silica in combination with potash and soda is spoken of as *soluble* and must be present in the clay. Too much iron and gypsum are objectionable; of the latter from one to two per cent may be tolerated. Caustic magnesia (MgO) forms a hydrate and sets with great hardness. When it and caustic lime (CaO) are present in uncombined form in the cement, however, the lime sets first and the magnesia later thus causing injury if the percentage reaches 4 to 5 per cent. Magnesia may be made to combine with silica and alumina as in the case of the lime but the hydration of its compounds is also slower than those of calcium. In order to show the composition of some of the mixtures from which English Portlands are made the following table is reproduced from Redgrave.[†]

TABLE XIV.—COMPOSITION OF ENGLISH PORTLAND CEMENTS.

Ingredients.	Folkestone, chalk and clay.	Forest of Dean, limestone and clay.	Barrow Lias, quarry mixture.
Sand	2.50	5.57	2.58
Silica	11.83	9.61	11.41
Ferric oxide	1.97	2.42	2.34
Alumina	5.23	3.45	4.80
Iron pyrite	Trace.	....	.43
Calcium carbonate	74.18	75.89	74.09
Magnesium carbonate	1.29	1.50	2.61
Calcium sulphate	.18	.16	.21
Potash	.90	.88	.93
Soda	.31	.39	.46
Water	1.82	.61	.43
	100.21	100.48	100.29

---

[*] A Manual of Lime and Cement. 1893. p. 42.

[†] Calcareous Cements, their Nature and Uses, p. 45.

Mr. Homer Wilcox in his tests of Monroe rock added alumina to the Ida dolomite thus preparing a Portland type of cement. In his letter he gives the following statement of his results.

> "I made mixtures of this Ida quarry rock in varying proportions with clay from various sections of Michigan and some from other states, but found no practical results, except in case of one particular kind of clay obtained from the coal mines of Jackson county, Michigan. I ground Ida quarry rock into flour without burning and mixed it with clay from the coal strata at Jackson, about ¼ clay and ¾ rock. Let it dry into soft bricks after mixing—then burned. It became very hard and slightly vitrified. This product I ground after burning and it was a pure hydraulic cement and the specimens from it superior in firmness, heft and hardness to any Portland cement I ever used, whether made in the United States, England or Germany. It cost too much, however, to manufacture for market and I abandoned the intention to place it on the market for that reason. I tried the same clay with limerock from other sections of Monroe county, but did not obtain the same results."

It is to be expected that the high percentage of magnesia in the dolomites of the Monroe series would prevent their use for such cements. In the quarries upon the Macon, however, as pointed out in preceding sections, limestone of sufficiently high grade occurs. The bed of marl south of Monroe (§ 11 of this chapter), is suitable also for this purpose but not enough of it is in sight. The clay deposits which constitute the till are too stony and sandy for use with the carbonate. The most promising deposits are in the southeastern parts of the county, Erie, La Salle and Monroe townships, where clay sediments from the glacial lakes occur most abundantly. These deposits are freest from pebbles and have a relatively small percentage of sand.

§ 6. Road metal.

The nature of the soils and the flat slopes conspire to give Monroe county exceptionally poor roads. In certain sections the roads are practically impassable for any kind of conveyance for several weeks of the year. Aside from the mere convenience and pleasure of the residents good roads are sadly needed in order that crops and farm supplies may be more economically transported. The economy arises from the saving in time, horseflesh, wagons and harness and the fact that crops may be marketed when the price is most advantageous, rather than simply when the highway permits. With a system of hard roads much of the necessary farm teaming may be done when the clay soils adjoining are not fit for cultivation and thus the time of the farmer, his hired help and team disposed to better advantage. Three tons may be drawn upon a good road with greater ease and less expense than one ton upon a poor road. Some 10,000 representative farmers from all parts of our country were called upon for estimates as to the cost per mile of hauling one ton of produce to market. The average cost for the entire country was 25 cents while in certain sections of New Jersey where the roads have been improved by a system of state aid the estimates averaged from seven to ten cents, making a saving of from 15 to 18 cents to the mile for each ton of produce.* In consequence of this saving there is at once an increased valuation in all property that secures the full benefit of improved roads. In the neighboring state of Indiana some 40 to 50 representative farmers who have lived under a system of poor and later of good roads have estimated that the increase in the market value of their land is $6.48 per acre, which is believed to be a very conservative estimate. But even this low estimate would mean an increase of $4,147.20 for each section of land. The total estimated annual loss from poor roads for a hundred acre farm is given by the U. S. Bureau of Agriculture† as $76.28, or a little less than $500 annually for each section. This loss alone in six years would construct and maintain an excellent stone road past every farm house in the county. In the Circular No. 28 above referred to, Director Roy Stone of the Office of Road Inquiry, quotes a Canandaigua farmer, whom he had questioned concerning his extra taxes as saying, "In this one week, by the advantage of having these stone roads and getting to market with my hay when it sells at a good price, my teams have earned $5.00 every day, while my neighbors' teams on the other roads are eating their heads off. We could not afford not to have these roads; we do not care anything about the taxation."

There are no available deposits of gravel in the county such as occur in Lenawee and Washtenaw counties, but Nature has given Monroe inexhaustible supplies of still better road metal and distributed it so that it is fairly accessible from all parts of the county. When the dolomites and limestones are crushed and spread over a road bed, which is properly drained, the surfaces of the stone become firmly welded and a very solid foundation results. It is not necessary to treat the entire road with crushed stone but simply one-half of it leaving a dirt road alongside, which at certain times is as satisfactory for driving as the compacted stone. This reduces the expense of construction and maintenance very considerably and is now being tried about Canandaigua, New York, with gratifying results. The stone used there are common field boulders which are drawn

---

*Circular No. 28, U. S. Dept. of Agriculture, Office of Road Inquiry.
†Circular No. 23.

from the land by the farmers at a good price per load, thus ridding the land of a serious incumbrance. Those of a single region are heaped together at a convenient spot and finally broken up by a portable crusher owned and operated by the township. The crushed stone are then distributed by local teams.

An excavation from 10 to 12 inches deep and 8 feet wide is made to receive the stone. Experiments, however, have shown that a six inch layer is satisfactory for ordinary roads, although 9 to 10 inches would probably be found more economical in the end. This thicker bed would require about 1300 cubic yards of crushed stone to the mile, which at the Monroe crusher would cost, at present prices, $780. The cost of transportation, preparation of the bed and spreading of the stone would have to be added. In some sections of the county the railroads are willing to carry road materials at the cost of transportation for the sake of encouraging improvements. In one sense every such road constructed is but an extension of the railroad to the farmers' residence. As the roads are ordinarily laid out it would be necessary for each section to become responsible only for two miles of road in order to completely cover the county. At first, however, only a few roads radiating from the main centers would suffice and these could be located with reference to the individual assistance that residents along the routes would be willing to render. Undoubtedly the expense of road construction could be very materially reduced by having each township, or adjoining townships, own and operate portable crushers. In 1896 such a crusher was worked by private parties in the eastern part of Whiteford township. A temporary tramway was laid and the stone were used in constructing one of the excellent roads leading out of Toledo. In only a few localities in the county are field stone abundant enough for such use. If the amount of time and labor that is ordinarily expended in improving (?) the roads could be more wisely directed great good would result.

Four permanent crushers have been constructed and operated in the county but two have ceased working. One of these was located alongside the Michigan Central just south of Newport Center and the other on Plum Creek at the quarry of the Detroit Stone and Supply Co. Those still in operation are at Woolmith and at the quarry of the Monroe Stone Co. north of Monroe. At Woolmith there are some beds capable of yielding a good quality of rock for macadamizing purposes, but the bulk of the rock possesses so much sand that it more readily crumbles and probably does not bind its fragments together so firmly. A more even type of dolomite is being crushed north of Monroe, the quarry having been operated almost continuously since Sept. 1, 1895. (See Plate IV.) The market is principally Detroit, but shipments are made to Saginaw, Bay City, Jackson, Adrian, Toledo, etc., the quarry being favorably located with reference to the Lake Shore, Michigan Central and Pere Marquette roads. During the season of 1899 this company shipped 55,706 tons at an average price of 60 cents per ton. Three grades of stone are supplied ranging from ½ to 2½ inches in diameter. The "Screenings" are used for cement sidewalks and are sold at twenty cents per ton.

As reported to the United States Geological Survey the total value of the limestones and dolomites marketed in Monroe county during the year 1897 was $29,812; for 1898 it equaled $23,779 and in 1899 was $43,183.

§ 7. Glass sand rock.

The bed of Sylvania sandstone has been described in considerable detail in Chapter III, § 6. It is so friable that it has no value for building purposes, although blocks firm enough for foundations have been taken from the Raisin bed. The chief use of this remarkably pure bed is the manufacture of glass, for which its fine even grain and purity well adapt it. It had been tested for this purpose before Michigan became a state and attention was especially called to the bed by Hubbard, Winchell and Rominger in their state reports. The outcrop was originally preëmpted from the government by Col. Thomas Caldwell, a British officer, and held by him and his heirs for many years. Charles Toll of Monroe has owned 60 acres of this land for over 40 years and for some time back has held sand and mineral rights on 150 acres adjoining. From 1860 until about 1873 or 4 the pits were operated by Toll, the sand being washed and sifted and shipped to Bridgeport, Bellaire and Benwood, Ohio; to Pittsburg, Wheeling, Rochester, Syracuse and Hamilton, Ontario. The sand was said to have been removed to a depth of twenty to twenty-five feet. The sand had to be teamed seven miles over a sand road and this so greatly increased the expense that it was finally unable to compete with beds more favorably located. The sand has been found to mix intimately with the fusible bases so that it melts rapidly and yields a glass free from color. Recently this land of Toll and his mineral rights have been leased by the Michigan White Sand Company, with headquarters at Maybee, Michigan. (W. H. Cowles, President and F. G. Strong, Secretary.) This company has put up a small experimental plant, in which the sand is heated to 400° F. without washing and then sifted, thus securing several grades of purity and fineness. A larger plant is contemplated which will have a capacity of 150 to 200 tons daily. The sand when washed gives no iron, traces only of calcium and magnesium carbonate and 99.59% of silica, thus showing very superior qualities for higher grades of glass. The whitest sand is said to be reached at a depth of two feet in the bed. By following the bed in the direction of the dip, as well as laterally the quantity is practically unlimited. Proceeding northwestward a capping of dolomite would soon be reached which would form a good roof in case it was desirable to mine the sand. The bed will be found to drop at about the rate of 25 feet to the mile.

The organic stain found in the upper part of the bed at the outcrop would be expected to disappear beneath the clay and dolomite. The course of the sandstone across the county is shown upon Plate I from which it is readily seen just where it is crossed by the various lines of railroads. A further examination of Plate XV will show the approximate thickness of the drift at each locality in case it might be desired to get to the sandstone by sinking a shaft through the drift. It should be noted that the full thickness of the bed would be obtained only by striking it on the western or northern edge of the belt. In case a test shaft happened to first strike the dolomite, the sand would be found just beneath and the dolomite would serve as a roof. As a rule the bed yields water in abundance and in mining the sand this water would have to be bargained with. It is not improbable that this water which it would be necessary to pump from any opening made into the bed would be quite sufficient for washing the sand. This sand has had several minor uses for which it is well adapted on account of its whiteness and sharp cutting edges. It makes a beautiful painters' sand, is very popular with the Diamond Match Company for use upon their match boxes and is unexcelled for scouring purposes, for which it is used locally. Soap charged with this sand would probably rival "Sapolio" for rough cleaning.

§ 8. Brick and tile.

The manufacture of brick upon a small scale was begun at a very early day to supply local demands. At the time of the Houghton Survey, Frenchtown had produced a total of 1,600,000. One kiln had been burned at Brest and about 100,000 at Newport. A trial had been made at Dundee and abandoned on account of the calcareous nature of the clay. Good brick were said to have been made in London township from clay obtained from the Saline valley. No statistics relating to the gradual development of the clay industry in the county are available. In 1896 the total value of the clay products was $15.720 and for 1897, $12.410. During the season of 1898 there were manufactured in the county, 2.112.100 brick, valued at $10.535 and tile valued at $12,470, making a total of $23.005. For 1899 there were burned 1,625.000 brick and 1.165,000 tile, having an approximate total value of $23,000. The position of the eight factories now in operation is shown on Plate XV. In 1896, at the time of the first inspection of the county for this report, two others were operating, one at Dundee and the other at Erie.

Notwithstanding the inexhaustible supplies of clay within the county, owing to its method of formation and accumulation, it is so charged with pebbles, many of them calcareous, as to be worthless for brick and tile. Upon burning, the fragments of carbonate are converted into lime, which will eventually slake and ruin the article containing them. Mechanically also they injure the soft brick and tile as they are forced through the die. This difficulty is in part obviated by running the clay first through a "crusher," which reduces the pebbles to coarse sand. From the till clays of various texture and purity could be obtained by a process of washing, but the time is not at hand when this would be profitable for ordinary use. Nature has, however, done considerable of this and deposited a washed product along the river valleys from which a good grade of brick and tile may be manufactured. Such clays usually contain sufficient sand to prevent warping and shrinkage in the process of burning. The sites of former lakes frequently contain clay of a very homogeneous character, which was washed in from the surrounding region. Such beds are generally only from one to three feet thick and in many cases underlie layers of muck and marl. This action took place upon a much larger scale in the case of the great glacial lakes described in Chapter VI, so that in the eastern, and particularly the southeastern corner of the county the superficial clays are to a greater or less extent utilizable. Whatever the color of the clay it burns in all cases to a cherry red, owing to the conversion of the iron compounds into the red oxide (Fe_2O_3).

The old method of moulding brick by hand has been discarded, but a near approach to it is still found in the "soft mud process," used at Monroe. The clay is brought into a soft, pasty condition by the use of water and kneading machinery, and then forced into sets of moulds, similar to those formerly used in the hand process. These moulds are emptied and resanded by hand, the bricks being spread in the yard to dry, where they are liable to be injured by the weather. Such brick are open grained and porous, but do not show the cracks about the edges and corners which so frequently occur in brick forced through a die. In the "stiff mud process," which is the one very generally employed, the clay is moistened sufficiently to become plastic but is at all times stiff enough to hold its shape. There being less water to be gotten rid of the drying takes place under long sheds. The stiff clay is forced by means of an auger or plunger intermittently from the machine through the openings in a steel plate. These openings are of suitable size and shape to give the clay its desired form and it is then cut into proper lengths, during a period of halt, by a frame carrying tightly stretched wires. Bricks made by this process are more compact, have a smoother surface and are stronger, but quite generally show cracks along the edges and other imperfections, due to the action of the die and the imprisoned air. Most of the kilns used in burning the brick and the tile are of the "up-draft" pattern but there are a few "down-draft" kilns in operation. In this type of kiln the heated air is admitted at the top and is compelled to pass downward before it can escape, thus giving a much more even burning to the brick and tile. The following data relating to the factories were collected in September, 1899:

Milan Brick and Tile Manufactory, owned by the Farmers and Mechanics Bank of Milan, H. S. Knight, Manager. Located alongside of the Wabash railroad, N. E. ¼, S. W. ¼, Sec. 2, Milan township, within one-fifth mile of the Ann Arbor road. The clay for tile is of a bluish variety obtained from the Macon Creek in N. W. ¼, Sec. 14, place of Warren Lewis; from 6 to 10 inches of muck have to be removed. Six feet of clay may be worked before it becomes stony. The brick clay is obtained from the Saline, Sec. 1, Milan, place of O. W. Leonard, and is of a yellow color and sandy. Stiff mud process; Brewer machine, with a capacity of 20,000 brick and 8,000 tile daily. One double up-draft kiln. The engine used is 25 horse power and about 20 hands are employed. During the season of 1898 the company manufactured 100,000 brick and 120,000 tile; in 1899 about 280,000 brick and 125,000 tile. The markets are mostly local, but shipments are made along the railroads as far as Toledo and Detroit.

Meyers Bros., Azalia, Ann Arbor railroad. Clay is obtained from bed of the North Branch of the Macon and is a mixture of blue and yellow as worked. From four to six inches of muck are first removed, below which is 1½ feet of blue clay and still lower 3 to 6 feet of yellow before a bed of gravel is struck. The factory has been in operation 6 years, and employs about 14 hands. A Brewer machine is used, driven with a 35 horse-power engine, capacity 12,000 of 3 inch tile and 24,000 brick; down-draft kiln. Markets are local and shipments to various points in Monroe and Washtenaw Counties. Tile are made from 2½ to 8 inch. During 1898 there were put out 225,000 brick and 220,000 tile; during 1899 from 250,000 to 275,000 brick and about 250,000 tile.

Charles Jacobs, S. W. ¼. S. W. ¼. Sec. 34. Summerfield. The clay is a local deposit found just north of the factory. There are 6 to 7 inches of muck and loam, beneath which lies 2½ feet of streaked blue and yellow clay, before clay carrying pebbles is reached. This plant was operated for several years by Wadsworth and Harwick. The machine used is a Brewer with a capacity daily of 15,000 3 inch tile and 15,000 brick. Markets are entirely local as there are no shipping facilities. During the season of 1899 there were manufactured here about 45,000 brick and 300,000 tile. Down draft kiln.

Mrs. Katharine Stout. Ottawa Lake Charles Jewell, foreman. A streaked yellow clay is used obtained near at hand, carrying some pebbles. Stiff mud process; Adrian machine, No. 2; steam power. One down draft kiln in repair. Only tile are made here and mostly 3, 4 and 6 inch; but ranging from 2½ to 10 inches. Capacity of machine is 6,500 of 3 inch. During 1898 there were burned 200,000 tile and about 100,000 in 1899. The factory is near the Adrian-Toledo branch of the Lake Shore and shipments are made as far as Toledo.

August G. Matthes, Strasburg. Adrian-Monroe branch of the Lake Shore R. R. Clay used is a blue and yellow streaked bed three feet thick, beneath which is 6 to 8 feet of blue clay (till). Clay is somewhat stony but not sufficiently so to cause serious trouble. Machine is an Adrian, No. 2, stiff mud process. Capacity daily 14,000 brick and 13,000 3 inch tile. Employs 7 to 8 hands. One up draft kiln. Last season Mr. Matthes made 250,000 tile and 150,000 brick and in 1898 200,000 tile and 125,000 brick. Markets are entirely local. Brick sell for $4.50 to $6.00 per thousand in the yard. The following prices per thousand are secured for tile: 3 inch $9, 3½ inch $12, 4 inch $14, 5 inch $17, 6 inch $25, 7 inch $35, and 8 inch $40.

Robert C. Herkimer, N. E. ¼. S. E. ¼. Sec. 18, Exeter. Operated by Frederick Linenfelser. Clay used is of the yellow variety and obtained from the Saline flats. Brewer "6 A" machine; capacity 25,000 brick and 12,000 3 inch tile. Engine 25 horse-power; six hands; one up draft kiln. In 1898 there were burned here 150,000 brick and 140,000 tile; in 1899 about 250,000 brick and 60,000 tile. The markets are purely local. Tile of the 3 to 4 inch size are mostly made, but range from 2½ to 8 inch. The prices are about the same as those above given for the Strasburg factory.

John Strong and Sons, South Rockwood, Michigan Central railroad. Clay obtained from surface near plant, bluish-yellow. The sod only is stripped off from the bed, five feet of which are usable. The pebbles present are first crushed. Adrian machine; stiff mud process for tile, soft mud process for brick. Engine 50 horse-power; daily capacity 30,000 brick and 10,000 to 12,000 3 inch tile. Two stacks for brick and two down draft kilns. 13 to 14 hands employed. During season of 1898 400,000 brick and 250,000 tile were made, but owing to overstocking none were burned in 1899. Markets are local, to points in Monroe and Wayne counties and north of Detroit. Tile from 2½ inch to 8 inch are made, but the demand is chiefly for 3 and 4 inch. The prices are for 2½ inch $8, 3 inch $9, 4 inch $13 and $6 for brick.

Charles G. Eaton, Monroe. Pere Marquette R. R. and Adrian-Toledo branch of the Lake Shore railroad. A yellow stony clay is used from a local deposit. A crusher removes the coarser pebbles and crushes the smaller. Soft mud process for brick. The bed of clay used is 3½ feet thick, from which only the surface has to be stripped. Sand has to be added to the clay. Brewer machine is used, with a 25 horse-power engine, capacity 30,000 brick daily. About 20 hands are employed. Up draft kiln for tile. Sizes range from 2½ to 8 inch, with most of 3 to 4 inch. In 1898 about 640,000 brick were burned and about 80,000 tile; in 1899 about the same amount of brick and about 65,000 tile. Markets local at about the same prices as above quoted.

§ 9. Natural gas and oil.

Covering the northwestern part of Monroe county as shown upon Plate XV there is an area over which there are strong surface indications of oil and natural combustible gas. This area covers Milan, London, Dundee, western Raisinville, nearly all of Summerfield and the northwestern corner of Ida townships. The oil impregnates the rocks and forms a scum over the water of ponds, streams and wells, giving it sometimes a very offensive odor. The gas bubbles up through the water, sometimes as a continuous stream, usually only as occasional bubbles. Still more of it escapes into the air without being noticed. Where especially abundant in wells it burns upon being ignited, giving a hot but only slightly luminous flame. It has comparatively little odor, by which it may easily be distinguished from the offensive, hydrogen sulphide gas (H_2 S) which is found in wells, imparting to the water the odor of "rotten eggs." From carbon dioxide gas which may also occur in wells and springs it is distinguished by its combustibility, since this former gas not only will not burn but will not support combustion. As pointed out in Chapter II this gas and oil are more directly associated with the St. Clair, Traverse and Dundee formations and are most abundant in Milan and London townships. This is known as surface or shale gas, can have no great volume and rarely ever any great pressure. It does not occur at definite horizons, is not associated with oil, salt water or any definite rock structure. The gas obtained from the drift deposits, in all probability, is derived from the underlying rock formations. The only practical use for this gas is for domestic purposes for which it has been but little utilized in the region. Piped into the house and used economically it would last for a number of years, when a new well could be sunk at but little expense and a new supply obtained. This should be looked upon as one of the resources of the farm and should be as carefully husbanded. The gas is not as valuable for illuminating as for heating purposes owing to its lack of luminosity. An Ohio man has discovered that if the fire brick of the grate are occasionally sprinkled with salt a more luminous flame may be secured.*

There is no necessary connection between this surface gas and oil and the deeper seated deposits so eagerly sought for by means of deep borings, since both may have been separately produced. At Findlay, Ohio, however, before the wonderful discovery was made such surface indications had been known for many years. At ten different places in the county deep wells have been drilled at heavy expense with the hope that some such deposits would be discovered as those which have made northwestern Ohio famous. Six of these wells have penetrated the Trenton limestone, the productive horizon in Ohio, but without adequate returns. (For records see Chapter III § 8). From data thus obtained it is apparent now why these wells have failed and there can be no justification for further expenditure to secure oil and gas from the Trenton within the limits of Monroe county. The gas and oil fields of Ohio and western Ontario are located along the crest of the great Cincinnati anticline, an uplift in the Trenton and overlying strata. This upheaval began in Silurian times, but was arrested, and the final folding as determined by

---

*In some districts of Ohio this "low pressure drift" gas has proved to be of commercial value. The use of Welsbach burners might remedy the lack of luminosity.

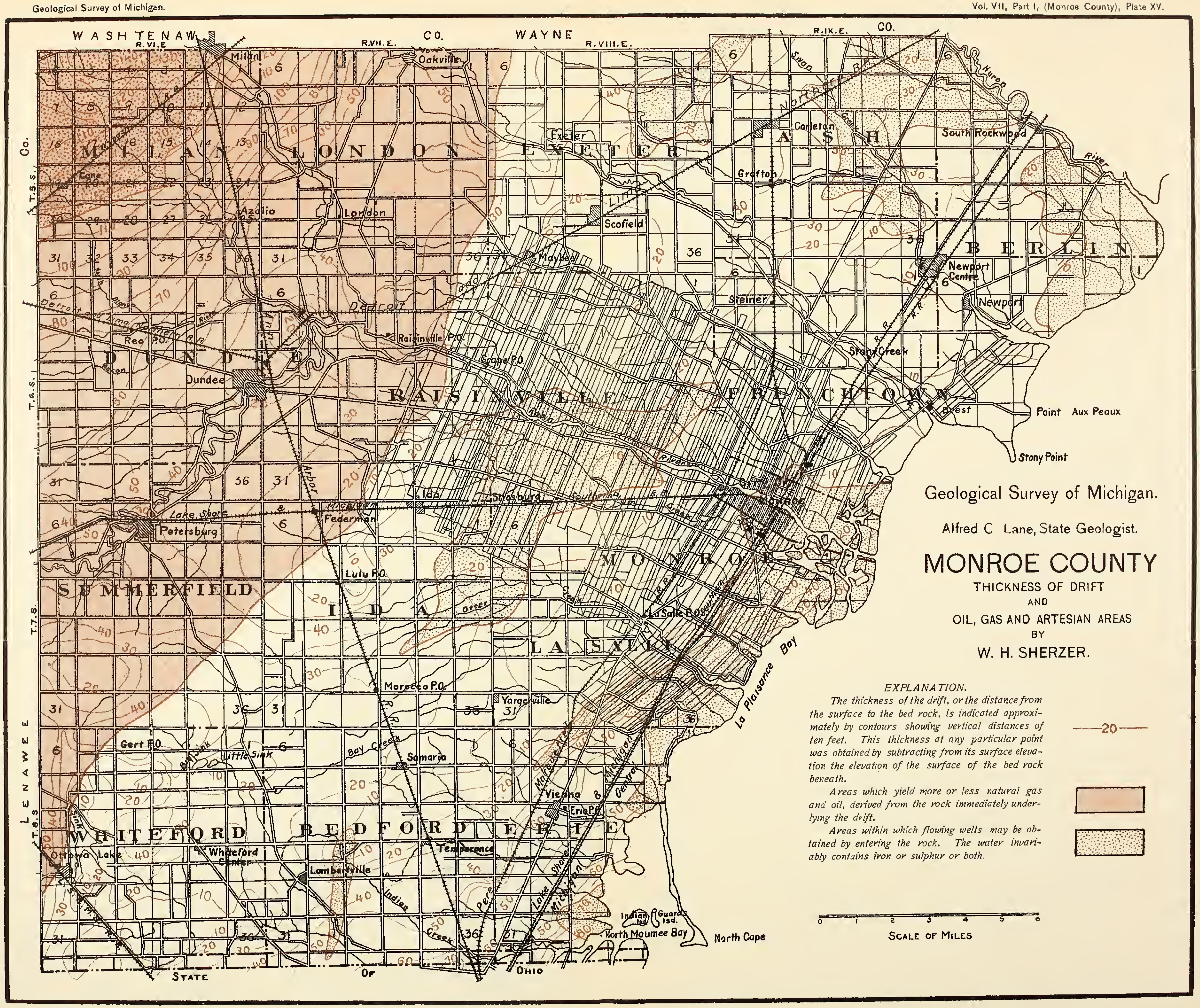
Foerste[*] took place in the late Devonian or early Carboniferous. As mapped by Orton[†] this anticline passes northward from Findlay to the east of Toledo, passing under Lake Erie and reappearing in Ontario. In a paper read in 1887 before the Royal Society of Canada.[‡] Robert Bell says:

> "There seems to be no doubt that the occurrence of petroleum in Enniskillen is connected with the Cincinnati anticlinal, but the writer, after having done a considerable amount of geological work in Western Canada at various times since 1859, and having carefully studied the question, has come to the conclusion that this anticlinal, coming up from Ohio, does not run eastward, as Logan supposed, into Lake Ontario, but that it maintains its northward course, and runs into the southern extremity of Lake Huron." * * * "Northward of Lake Erie, an impartial study of what is actually known of the geographical structure, as well as of the distribution of the formations, indicates that its axis, after crossing the lake, continues on, as we would naturally expect it would, in the same general north-northeastward direction bearing through the counties of Essex, Bothwell and Lambton, from about Littles' Point on Lake Erie, to about Kettle Point on Lake Huron."

From this quotation and the figures given in Chapter III, § 9 concerning the drop in the Trenton towards the north and west it will be apparent that Monroe county is unfortunately placed upon the western slope of this productive anticlinal. The higher portions are to the east and south and towards these directions the oil and gas have been drained. The most promising part of the county for a test well was theoretically in the southeastern corner since this is nearest the crest of the anticline. Of all the ten deep wells the one nearest this region has proven most productive. This well was begun in November, 1898, and completed December 10th. It is owned by F. C. Potter in the N. W. ¼, N. W. ¼, Sec. 22, Erie township. The Trenton was struck at a depth of 1,555 feet, (see Chapter III, § 8), and entered 112 feet. The original gas pressure was 25 pounds to the square inch. It has been piped to the house and is used for lighting and cooking. The well contains oil and has been several times bailed out, some ten barrels having been thus secured in August, 1899. Most of the other wells have given some temporary showing, enough to raise the hopes of the stockholders, but none of them have done as well even as the Potter well. The three Monroe and the two Dundee wells have furnished decisive tests so far as the penetration of the Trenton is concerned. According to Orton, who followed very carefully the development in Ohio, the productive part of the Trenton is usually confined to the first 15 feet. In his report of 1888, [§] he says

---

[*] American Geologist, Vol. VII, 1891, pp. 97 to 109.
[†] Ohio Geological Survey, Vol. VI, pp. 46 to 55.
[‡] Trans. Roy. Soc. of Can., 1887, p. 105.
[§] Geological Survey of Ohio, Vol. VI, p. 118.



Geological Survey of Michigan.

Alfred C. Lane, State Geologist.

MONROE COUNTY

THICKNESS OF DRIFT
AND
OIL, GAS AND ARTESIAN AREAS
BY
W. H. SHERZER.

EXPLANATION.

The thickness of the drift, or the distance from the surface to the bed rock, is indicated approximately by contours showing vertical distances of ten feet. This thickness at any particular point was obtained by subtracting from its surface elevation the elevation of the surface of the bed rock beneath.

Areas which yield more or less natural gas and oil, derived from the rock immediately underlying the drift.

Areas within which flowing wells may be obtained by entering the rock. The water invariably contains iron or sulphur or both.

> "Thus far, unless some gas or oil is found in the uppermost sheets of the Trenton limestone, none is found below, and in but one case have valuable accessions to the supply been made more than fifty-five feet below the top of the rock. There are scores of instances now on record, all agreeing as to this point, and yet most of the wells that fail to find gas in the proper horizon are carried down 200, 300, 400 feet into the solid limestone before being finally abandoned. Such expenditures are a dead loss to the investors, and are generally of but little value to the drillers. The same perversity shows itself in multiplying wells after one or even after repeated failures in territory which must be counted on highly probable grounds as unproductive."

Gas and oil have had a common origin which is now generally believed to have been from the decomposition of organic matter, animal or vegetable, or both, which was originally deposited in the sedimentary rocks. There is a divergence of opinion as to whether the gas and oil were produced from the original partial decay of the organic matter at the time of its deposition, or later as a product of slow spontaneous distillation.* Probably the view that now receives widest acceptance is that these products have resulted from the decomposition of organic matter, at normal temperatures, either at the time the rocks were formed or later. The oil and gas may still be associated with the original beds in which it was formed or it may have escaped upward until its progress was arrested by impervious beds of suitable shape to confine it. In case no such beds existed it would escape to the surface and be lost. As might be expected from their method of formation limestones and shales would be the only beds with which any considerable amount of organic matter would be associated and in such beds oil and gas are believed to have originated. The organic matter of limestones was in the main of animal origin and gave rise to a dark heavy offensive oil containing a relatively large quantity of sulphur and nitrogen. It is oil of this nature that is found in Ohio and western Ontario. Oil derived from shale is in the main of vegetable origin and is lighter in color, contains less sulphur and nitrogen and has not the offensive odor of the limestone oils. Most of the oils of the Pennsylvania region are of this nature. Fissured limestones, sandstones and conglomerates serve as reservoirs for oil and gas, usually with an arched capping of shale. Where salt water, oil and gas all occur they are arranged in the order of their specific gravities; the gas would first be reached in the boring, would escape, give place to oil eventually and lastly to salt water. It is thus apparent why the crests of anticlines and of domes are so productive of oil and gas and why the slopes may prove barren, or yield a small quantity of oil or salt water only.

---

*See Geol. Sur. of Mich., Vol. V, Pt. II, pp. xix to xxiv.

§ 10. Artesian water and mineral springs.

Three belts of artesian water strike across the county in a northeast and southwest direction,—an eastern, a central and a western belt. Within these areas, when the rock is penetrated a short distance, the water generally rises to the surface and flows, thus saving the expense of windmills and the trouble of pumping for stock and for irrigation. This water is very generally charged with compounds of calcium, magnesium, iron and sulphur, derived from the limestone, dolomite and shale through which it has passed. The iron and sulphur are derived largely from the decomposition of the pyrite and marcasite, which are very commonly present in these rocks. Hydrogen sulphide gas is produced which is readily absorbed by the water, to which it imparts the odor of "rotten eggs." Upon exposure to the air this gas is decomposed and the sulphur is precipitated as a white mealy precipitate over troughs, stones and vegetation. When in quantity and after standing it begins to assume a slight sulphur yellow color. The iron is present in the water mostly as a carbonate and upon standing it is oxidized and deposited as a yellowish brown coating over objects, this being the hydrated oxide. This is insoluble in water and is readily distinguished by its color from the sulphur. When both iron and sulphur are present in the water in the form described a chemical combination takes place and iron sulphide results, giving the water an inky black color. A number of wells of this character were met with in the county, although the water of a region usually contains one or the other of these substances alone. In some instances artesian water is derived directly from sand and gravel layers in the drift and is reported as soft.

Continued drought makes no perceptible impression upon many of these wells, while with others the flow may be reduced and almost or quite stopped. The opening of new wells has been found to affect the flow of others in the neighborhood and the areas over which artesian water may be secured are becoming more contracted. Wells which formerly flowed in the southern part of Erie township, back three miles from the lake, have now ceased although the water rises to near the surface. The opening of the Woolmith quarry in Exeter township had a noticeable effect upon the water in the wells to the northeast. The deep well in the eastern part of the city of Monroe so seriously interfered with the action of the wells of that region that it had to be plugged. At the place of Nelson Richards, S. E. ¼

S. E. ¼, Sec. 1, Exeter, a flowing well ceased to act when another was started at Welsey Richards' place, one-half mile west, but by compelling the latter to rise four feet above the surface both wells flow. Meteorological conditions are found to affect the wells in several very noticeable respects, more or less puzzling to their owners. These effects may be thus summarized:

William Young, N. W. ¼, S. W. ¼, Sec. 6, Milan. Gives a muddy deposit before a storm.

J. R. Vescelius, S. E. ¼, N. W. ¼, Sec. 6, Milan. Becomes roily before a storm.

Charles Campbell, S. E. ¼, S. E. ¼, Sec. 27, Milan. Water becomes roily when wind is in the southwest.

Brightbill Bros., S. E. ¼, S. E. ¼, Sec. 3, Exeter. Three to four hours before a storm gives a black sediment.

William Laurie, S. W. ¼, N. W. ¼, Sec. 6, Ash. Water gives a black deposit 12 to 14 hours before a storm.

Scofield, Exeter. Level of water in well said to be raised three feet by an east wind.

T. M. Taft, S. W. ¼, N. E. ¼, Sec. 7, Summerfield. Water stands higher with an east wind, lower with a west.

G. W. Dauncey, S. E. ¼, N. W. ¼, Sec. 7, Berlin. Water flows faster before a storm, but is not roily.

Charles Todd, S. E. ¼, N. E. ¼, Sec. 7, Berlin. Flowing well had nearly ceased to flow on account of clogging with sand but once just before a storm it broke out afresh and gushed with such noise as to be heard some little distance, throwing out much sand.

These phenomena may all be simply explained by the meteorological conditions that prevail before and during times of storm. The density of the air at such a time is reduced over the surface of the earth, so that its pressure on the column of water in the well is less. Air enclosed in the subterranean passages of the rocks is temporarily more condensed than that over the surface and its pressure upon the underground water, added to the regular hydrostatic pressure, causes the water to rise to a higher level, or to flow with greater force than usual. If sediment of any kind has been deposited in the underground channels the increased velocity of the flow will cause this to be again taken into suspension and the water becomes roily. The only supposable connection between the east wind and the height of the water in the wells is that the wind in this quarter frequently presages a storm.

The most western artesian area covers nearly the northwestern half of Milan township to the west of the Arkona Beach. It is a portion of a belt which extends from Lenawee county northeastward into Washtenaw. The artesian water is derived from the rock and from layers of the drift, which varies in thickness from 100 to 150 feet. Throughout this entire area the water does not always flow, lacking nine feet of reaching the surface in Milan village. The water rises from a few inches above the surface to 14 feet at Thomas Welsh's. Here one well at the barn rises higher and yields softer and warmer water than another at the house, near at hand. At the place of John Dennison, S. E. ¼, N. E. ¼, Sec. 20, a flowing well can be readily obtained anywhere by penetrating a bed of coarse gravel at a depth of 30 feet. The amount of water supplied by these wells is never large, the best of them simply filling a one inch pipe. The heaviest flow of the region is obtained from the crest of the Belmore Beach, one mile over in Lenawee county at the residence of James Harmon. A strong flow was secured from a depth of 48 feet, rising 9 feet above the surface. A 1½ inch pipe is filled and the water is used in the dairy. At the barn a similar well was struck and plugged because of the difficulty in disposing of the water. This water is impregnated with iron.

The middle belt referred to consists of three detached patches extending in a northeast direction across the county. The most southerly is a narrow area about three miles long by one-half mile wide in Bedford township, just east of Lambertville. Some fairly strong flows are obtained in this region but they rise but little above the surface. In the central part of the county there is a large irregular area over which flowing wells may be ordinarily secured (see Plate XV). The water contains sulphur commonly when it comes from the rock but sometimes iron. The highest rise noted is 5 to 6 feet upon claim 472, South River Raisin.

The most northern area of this belt occurs in northwestern Exeter and northwestern Ash and continues as a narrow belt northeastward into Wayne county for a considerable distance. This region contains considerable sulphur at times in combination with iron. Some of the wells proved so offensive and so injurious to the soil that they were plugged. A rise of three feet above the surface is above the average.

The eastern artesian belt lies near the lake shore and consists of four detached areas, one small one in eastern Erie, a second about the mouth of the Raisin and extending southwestward into Erie, a third in eastern Berlin and a fourth irregular one in northwestern Berlin and eastern Ash. In Brownstown of Wayne county the two latter areas unite and continue towards Detroit along the Detroit River. As might be expected the flow of water is stronger in these regions and the rise above the surface is higher. At the Greening Brothers' nurseries south of Monroe the water reaches the surface with force enough to run sprinklers and when compelled to do so will rise 12 feet. Eastward at Lake Erie at the Lotus House there are two flowing wells which will rise 20 feet above the surface or 25 feet above the lake. The water of the wells in this lake region is generally charged either with sulphur or iron, seldom containing both in such quantity as to become dark. The heaviest flow of artesian water known in this part of the state was struck in September, 1899, upon the south bank of Otter Creek, about 2½ miles southeast of La Salle, at the residence of Edward Sharkey. The well is 51 feet deep and 6 to 8 feet in the rock, having been drilled with a three inch drill. September 4th water was struck and began to flow, slowly at first and then with greater strength. A wooden

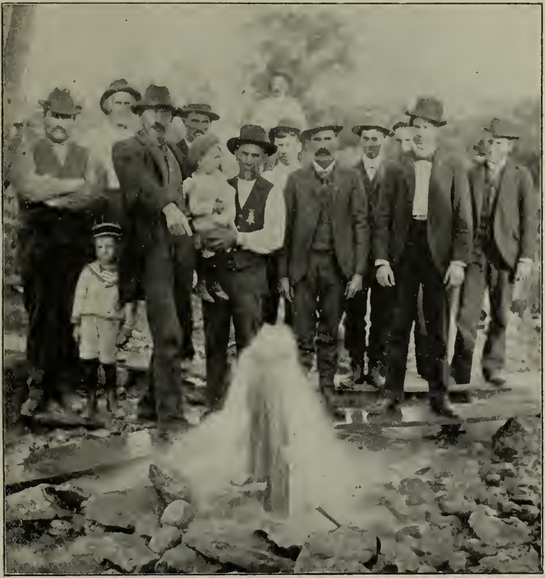


Fig. 7. Gushing well struck upon Otter Creek, September, 1899. Residence of Edward Sharkey, 2½ miles southeast of LaSalle.

pump-stock was driven into the hole and projected four feet above ground. Through this the water was thrown with force and to a considerable distance, latterly through 10 one and one-half inch holes bored in the side. Thus prevented from escaping freely the water began to rise through the clay around the mouth of the well and at a distance of 25 to 30 feet from it, forming a shallow lake about 100 feet across. By this time Mr. Sharkey became alarmed for the safety of his house and the pump-stock was withdrawn, an eight inch pipe being inserted in its place. At the time of the writer's visit a very rapid stream two feet broad and four inches deep was flowing from the well to Otter Creek. Fig. 7 shows the well as it appeared September 16, 1899, as taken by an amateur.

Within these artesian areas not infrequently natural openings have been made to the surface through which the water escapes and flows as a mineral spring. These are more common in the central and eastern part of the county, back from the river to a distance of two to three miles. Some of them sometimes occur outside of the artesian areas, for instance the sulphur springs near the foot of Ottawa Lake upon the farms of Harmon Branch and William Bell. A strong natural flow of sulphur water, with some iron, occurs at Christopher Nichols' claim 685, South River Raisin. This would fill a five inch pipe and is but slightly affected by drought, never drying up. Upon land belonging to Catherine Sorter, claim 673, South River Raisin, there is a strong sulphur spring which feeds Sulphur Creek. This has been known to stop flowing but twice, in 1875 and 1895. South of Monroe 1¾ miles is located the somewhat celebrated "Shawnee Spring," upon claim 160, South River Raisin, just east of the Michigan Central tracks. From 1860 to 1879 or 80 the place secured some note as a resort. The water is said to retain practically the same temperature throughout the year and to be unaffected by drought. An examination of the water was made in 1864 by Prof. S. H. Douglass, then of the University of Michigan, who reported that the water contained free carbonic acid, magnesia, and abundance of lime, chlorides and sulphates and that hydrogen sulphide would probably be found in the water at the spring. The spring has formed a large mound of sphagnum moss and calcareous tufa over 500 feet across and 8 to 10 feet high, through which the water escapes by numerous mouths. (See Plate XVI.) Quite large masses of this tufa are loose in the field and ledges of it occur in position. The

SITE OF SHAWNEE SPRING NEAR MONROE. MOUND IS POORLY SHOWN.

water tastes and smells of hydrogen sulphide and is depositing sulphur. Similar springs with mounds of tufa are found to the south, upon lands of Mrs. Adeline Q. Navarre and Joseph Asam.

A large sulphur spring occurs upon the place of Peter Cushino, Otter Creek, near the Sharkey well just described. This has an elliptical basin 45 by 90 feet, with a 10 foot margin richly covered with *Chara*. The stream from the spring is not rapid, is 2½ feet broad and 10 inches deep. A similar but much larger spring occurs in the Erie marsh near Vienna, N. E. ¼, Sec. 22. It is reached by boat by punting one-half mile through an artificial channel. At a distance the site of the spring is marked by a spot of the most livid green contrasting strangely with the dark waters of the marsh. The general form of the spring is circular as shown in Fig. 8 and its diameter is about 160 feet. The bottom is funnel-shaped, a marginal strip of 25 to 40 feet shelving off slowly and then making a sudden drop. The bottom where visible through the clear water is covered with a mat of *Chara*, encrusted with a deposit of sulphur. The sounding line struck bottom at 30 to 33 feet, although it is quite probable that fissures occur leading to greater depths. The outlet from the spring is a small sized river having considerable velocity, a breadth of 33 feet and a depth of one to two feet. The current is so swift that there is some difficulty experienced in entering the

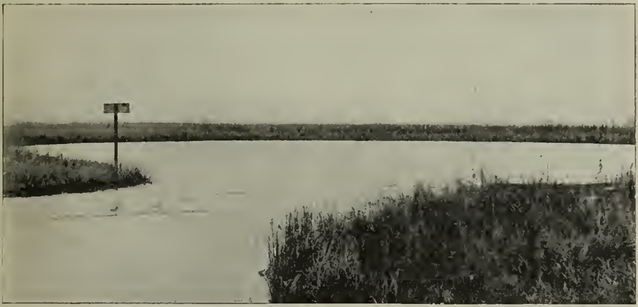


Fig. 8. Great sulphur spring in the lake marsh near Erie. The figure gives also a view of the inundated margin: cf. Fig. 5.

spring with a boat. The channel soon becomes broader and proportionately more shallow, and over the bottom of it much sulphur has been deposited. Fragments of tufa are found about the margin of the spring showing that the water is probably rich in calcium carbonate. It is very probable that these springs and flowing wells are fed by the water which enters the rocks in the western part of the county.

§ 11. Marl.

No extensive beds of this substance, for which the Portland cement industry has created a demand, are known to occur in the county. The largest deposit known occurs upon the property of Joseph Asam, claim 422, north of Plaisance Creek. Over an area of 6 to 8 acres there is a layer of black spongy muck containing many dead shells of *Helix*. Beneath this is found a bed of marl varying in thickness from one to three feet. The marl is so free from grit that, after washing, it has been found to produce a good polishing powder for gold, silver, nickel, brass etc. It was boxed and sold for this purpose some twelve years ago under the name Paragon Polishing Powder, being prepared by the La Plaisance Manufacturing Co. The marl contains some shells but appears to have been in the main precipitated from the water of a small lake charged with lime carbonate. Such a deposit may now be seen in process of formation over the bottoms of the series of lakes through which the Huron River flows in Washtenaw county. Upon claim 161, about one mile west of the Asam deposit at the place of Eli P. Duval, there is said to be a black deposit with white clay. The latter is undoubtedly marl and a similar reference to a 10 inch layer of "whitish dirt" was obtained at W. J. Kelley's, claim 520, South Otter Creek, where it is overlain by 2½ feet of yellow sand and one foot of black sand. Beneath the sand layer is one foot of yellowish-white clay, 1½ inches of gravel and then common clay to the rock. Judging from these deposits we have here a former lake site. At the cranberry marsh belonging to Clayton Everett, of Toledo (S. E. ¼, Sec. 24, Summerfield, see p. 157), more or less marl occurs, but the maximum thickness is said to be but 6 to 8 inches. It is quite probable that thicker deposits occur towards the center of the marsh, possibly of considerable extent. In his early report Hubbard reported marl as occurring on Sec. 7 of Exeter and Sec. 9 of Ash townships.* A very extensive marsh occurs in Sec. 9 of London and probably contains marl beneath the surface. It might be possible to dredge out here both marl and a suitable variety of clay for Portland cement. The clay would be found beneath the marl if both occur. Such use is the main one for this loose variety of lime carbonate. Its value as a fertilizer and for neutralizing the acidity of muck has been referred to in the previous chapter, p. 172. In the early days it was sometimes converted into lime by heaping it up into a pile and keeping a wood fire going around and over it until the carbon dioxide gas was driven off sufficiently.

---

*Second Annual Report of State Geologist, 1839, H. R. No. 23, p. 110.

§ 12. Salt.

Springs along the Saline River furnished a weak brine for the use of the Indians and pioneers, but the main one was in Washtenaw county (T. 4 S., R. 5 E., Sec. 12). In 1823 this spring was described as being 16 feet deep, set about with a picket of logs from which the surface water was excluded by means of an embankment. Salt was manufactured here on a small scale, an analysis showing 113.8 grains of salt in 100 cubic inches of the water.* Dr. A. Winchell, in his report of 1860 (p. 59) refers to a salt spring in Ida township, 4½ miles south of the Raisinville quarries. No such surface springs could be located by the present survey, probably owing to the diminished flow from wells and springs. In Berlin township, S. E. ¼, N. W. ¼, Sec. 15, at the place of A. Bondie, the well water is reported as being occasionally salty to the taste. In Lenawee county, north of Deerfield, this phenomenon is more common. Such indications are of interest now only as they suggest the presence of more extensive saline deposits beneath the surface. Undoubtedly the waters obtained from the deep wells of the county are highly charged with salt but no study has been made of them. In but one of these deep wells was there recognized a stratum of solid rock salt (halite) and in this case the report lacks verification. According to a newspaper item, at a depth of about 1,200 feet, a 12 foot stratum of salt was penetrated in the Frey well, near South Rockwood (N. E. ¼, N. E. ¼, Sec. 33, T. 5 S., R. 10 E). This occurrence was not to be expected since the records of the six wells at the Church and Company's plant north of Trenton seem to indicate that the St. Clair and Detroit River beds of salt give out between the most northern and most southerly located wells of their group. Well No. 6 gives a stratum of 33 feet while Nos. 4 and 1 and 3 lying in this order to the east give 30 feet, 26 feet and 25 feet respectively. Well No. 2 lies about 300 feet south of the above and shows but 2 feet of salt while in No. 5, some 800 feet south of the northern row, only a brine was secured with no solid salt. If the rumor in regard to the Rockwood well be founded in fact it will be necessary to assume that minor salt beds were deposited south of the main series after the inland sea had begun to break up into separate bodies of water (Chapter III, § 5).

---

*First Annual Report of the State Geologist, 1838, H. R. No. 14, p. 28.

CHAPTER IX.

MINERALS OF MONROE COUNTY.

§ 1. Introduction.

In this chapter it is desired to describe in simple language the native minerals so that they may be readily identified by those interested, even if they possess no previous scientific knowledge or training. After a mineral has been recognized the question of its formation and source becomes of more or less interest and importance, so that the history of the various mineral deposits will be briefly presented. There are excluded from the list all those minerals which were formed to the north and east and which were transported to the region under study by ice or other agency. This chapter will then be of little service in identifying the constituents of the drift boulders strewn over the surface or embedded in the soil. Almost any mineral known may occur in them. It will treat only of those mineral substances which were formed within the limits of the county, some of which are at the surface but most of which are contained in the rock strata and are now met with in the quarries and well drillings. A mineral has been defined as a natural, homogeneous, inorganic substance; but this definition, simple as it is, requires some explanation. It must have been formed entirely through the operation of natural agencies without the intervention of man. The substance itself must have practically the same chemical composition throughout, although it may have mixed with it more or less impurity. It must be of inorganic origin entirely, or if derived from plant or animal originally, its organic structure must have been practically destroyed.

A. *Carbonates.*

§ 2. Calcite.

This is the most common and widely distributed mineral of the quarries. It is found filling seams and crevices in the limestones and dolomites and forming beautiful sparry lining to fissures and cavities. The calcite may occur as a compact granular mass or in separate, well formed crystals. The crystals are commonly sharply pointed, each point being formed by three pairs of triangular faces, making what is known technically as a scalenohedron.* Such crystallization is known popularly as "dog-tooth spar," because of the resemblance of the crystals to canine teeth. Hubbard, in his early report, refers twice to the "hog-tooth spar" and it is not now certain whether this is simply a misprint or whether he intended to characterize a coarser variety of crystal. Another common form of crystal is the rhombohedron, looking like an oblique prism. Whatever the original crystal, upon being broken the calcite breaks with remarkably perfect cleavage planes parallel to the faces of the rhombohedron. The luster is more or less glassy and the color is various from impurities. The usual color is snow-white to a cream-yellow, but it is sometimes tinged with a variety of color. Clear transparent varieties are known as "Iceland spar," but in general, the mineral is simply translucent. It cannot be scratched with the finger-nail, but is readily scratched with a pin or knife, giving a white powder, the "streak." Its specific gravity is the average for rocks, 2.7. Its composition is calcium carbonate ($Ca\ CO_3$), and it contains by weight, 44% of carbon dioxide (CO_2), and 56% of lime (CaO). This gas may be readily driven off by the application of cold dilute hydrochloric acid to the solid crystal, causing brisk effervescence, so called. The acid of standard strength is prepared by taking four parts of pure water to one part of the acid, giving a 20% mixture. The Monroe calcite crystals have been deposited from percolating water holding calcium bicarbonate $CaH_2(CO_3)_2$ in solution. This form of the carbonate is easily converted into the common variety ($CaCO_3$) which crystallizes where conditions are favorable. Such conditions are commonly found in rock fissures and cavities where there is little agitation of the water which is charged with the carbonate. The finest crystals of calcite in the county are found at the Woolmith quarry, although some good specimens can be procured in the dolomites about Monroe.

§ 3. Aragonite.

This mineral was not identified by the writer amongst his collections but is said to have been found about Monroe.† It has the same composition as calcite, but has less perfect cleavage and is per-

---

*See Vol. VI, Part I, appendix, for report on crystallization of calcite.
†Dana's system of Mineralogy, 1892, p. 1086.

ceptibly heavier and harder. It does not show the familiar forms of the calcite crystals, the scalenohedron and rhombohedron. Its crystals may be either simple or compound, or may occur in radiating groups of acicular crystals. The latter is the common crystallization of strontianite (§ 6 of this chapter), and it is quite possible that this mineral may have been taken for aragonite. With the dilute acid calcite and aragonite behave similarly, so that they are liable to be confused with one another, unless crystallization and cleavage can be well made out. Upon being heated as with the blowpipe, they each whiten and glow, but the aragonite crumbles to powder while the calcite does not. The aragonite is liable to contain some strontia, which imparts an intense red color to the flame, making its separation from strontianite more difficult. The lime carbonate of many shells is in the form of aragonite as those of mussels and snails. Some corals and polyzoa form this same substance for their hard structures.

§ 4. Tufa.

This is a cryptocrystalline form of lime carbonate deposited over moss, twigs, leaves, etc., by spring water. The underground water carries the calcium bicarbonate in solution as explained in § 2. Upon having its pressure relieved and being exposed to the air some of the carbon dioxide escapes from the unstable bicarbonate, the monocarbonate results and this is so slightly soluble that it must be precipitated. Deposited thus quite rapidly over the surface of meadows there results an imperfectly crystalline, lumpy mass, more or less porous and open, showing the imprints and moulds of the organisms covered by the water. This is known as calcareous tufa, but where the structure is compact, one layer superimposed directly upon another, it is termed travertine. Iron is generally present in the water, the oxidation of which gives the tufa a yellow to brown stain. The structure of this material, its lightness and occurrence about existing or former springs are sufficient for its identification. A drop of cold dilute acid causes at once a vigorous effervescence, as in the case of calcite. The most extensive deposits of this substance are found to the south of Monroe, near the lake shore (Chapter VIII, §10). Where abundant it is sometimes burned into lime and occasionally used for building purposes. The writer has seen a very pretty country church near Rochester, N. Y., constructed of this tufa.

§ 5. Dolomite.

Just as calcite results from the solution and crystallization of pure limestone, so the mineral dolomite represents the re-crystallized magnesian limestone. Through the agency of percolating water, charged with carbon dioxide gas, this limestone is taken into solution. Little is known definitely in regard to just how it is held, but is probable that the calcium and magnesium carbonates, of which the dolomite is composed, are separate and each in the form of the bicarbonate, $CaH_2 (CO_3)_2$ and $MgH_2 (CO_3)_2$. Under certain conditions these bicarbonates are converted into the monocarbonates, the normal forms, and crystallize together so as to form crystalline dolomite in seams, fissures and cavities. Such occurrences of this mineral, however, are rare although microscopic rhombohedrons make up the granules of oölite and cover the grains of the Sylvania sandstone. The spring waters from beds of dolomite deposit calcium carbonate in the form of tufa but no corresponding deposits of magnesium carbonate (magnesite) were observed. The crystals of dolomite very commonly show curved faces, instead of planes, have a pearly luster and give perfect cleavage. The color is white or pink generally, but may vary from the presence of impurities. The mineral is brittle and has a white streak. It is slightly harder and slightly heavier than calcite, but is distinguished from it most certainly by use of the dilute acid. When a drop of such cold acid is applied to the solid crystal there is almost no action, but if the acid is heated or the dolomite is powdered the effervescence is brisk. This mineral is a double carbonate of calcium and magnesium, having the chemical formula $(Ca\ Mg)\ CO_3$. It contains carbon dioxide (CO_2) 47.8%, of lime (CaO) 30.4% and of magnesia (MgO) 21.7%. Expressed differently it has of calcium carbonate 54.35% and of magnesium carbonate 45.65%.

§ 6. Strontianite.

This is the last of the four minerals from which effervescence may be obtained by the use of dilute acid. A drop of cold acid upon the solid substance causes vigorous effervescence as in the case of calcite and tufa. As found in this county it is of a snow white color forming irregular masses in the cavities and fissures of the dolomitic limestone. Usually it has a loose open structure, composed of globular masses, which show a radially fibrous structure upon being broken. Over their surface and dipping down into the cavities is a layer of fine pyramidal points, producing a fuzzy, frosted appearance.

When the crystals are broken they show both perfect cleavage and uneven fracture faces. The mineral is brittle, gives a white streak, has a glassy to resinous luster and is sub-translucent. The color although usually a pure white may be altered by impurities. The hardness is about that of dolomite (3.5 to 4), so that it may be easily scratched with a knife. Aside from the structure above described, which is quite characteristic, strontianite is easily distinguished from the preceding carbonates by its relatively high specific gravity (3.7), surprising one at once with its weight. If a fragment is moistened with hydrochloric acid and held in the flame of a lamp, candle or gas, or even a burning match, an intense red color is imparted to the flame. This is the familiar "red fire" of the Fourth of July, or campaign celebration and is due to the element strontium, from which the mineral derives its name. The mineral occurs at Stony Point, Point Aux Peaux and Brest, and in the Plum Creek quarries near Monroe, also in the Ida and Little Sink quarries. At the last locality the finest specimens may be obtained in lumps of snowy whiteness the size of the fist and upwards, having been formed in the cavities of the dolomite. At the Ida quarry small masses occur in cavities but some of the upper dolomitic layers are partially converted into strontianite, over the surface of which is spread a layer of slender orthorhombic crystals. This occurrence gives a clue to the origin of the mineral, suggesting that it has resulted from the action of strontium salts in solution acting upon the carbonates of calcium and magnesium. The composition is represented by the formula $Sr\ CO_3$, of which 29.9% by weight is carbon dioxide (CO_2) and 70.1% strontia (SrO). The "tremolite" reported by Houghton in his first report as occuring at Brest was probably this strontianite. Larger quantities than are now in sight would give this mineral a high commercial value since it may be used in recovering beet-sugar from the waste "molasses" (Chapter VIII, § 4). After the process is once started the strontium is recovered and the only loss is that occasioned by the actual sugar loss. According to Prof. Wiley this loss of the mineral strontianite would amount to about 6¼% of the weight of the molasses treated. In the market this strontian carbonate is worth five to six cents a pound.

B. Sulphates.

§ 7. Celestite.

This is another compound of strontium, of much interest and beauty which is more abundant than the above. It is found in the fissures and cavities of the dolomites at Point aux Peaux and Stony Point, about Monroe and in the Raisinville and Woolmith quarries. The finest crystallizations are found at the last mentioned locality, where the mineral is intimately associated with calcite and native sulphur. These crystals are of the flat, tabular variety, with beveled ends and edges and attain a size of 5 to 6 inches in length, by 3 to 4 in breadth and have a thickness of one inch. Typically the color is a beautiful celestial blue from which the mineral derives its name. Some of the masses, however, are perfectly transparent and free from color while others are a pure white, or a deep chocolate brown. The crystals are brittle and break·with distinct to perfect cleavage faces, the luster is glassy and the streak is white. The mineral is easily scratched with a knife-point (Hardness = 3 to 3.5), being, generally, a little harder than calcite. A very characteristic property is the high specific gravity (4), it being even heavier than strontianite. From the preceding five carbonates described celestite may be readily distinguished by the action of hydrochloric acid, with which it cannot be made to give an effervescence. Chemically the mineral is strontium sulphate with the formula $SrSO_4$, containing of strontia 56.4% (SrO) and of sulphur trioxide (SO_3) 43.6%. Under the blow-pipe is readily fuses giving the intense red color to the flame. The occurrence of celestite in closed cavities in the dolomite, and its practical insolubility in water and acids, shows that its ingredients must have been introduced through the agency of percolating water and the mineral formed in place. A saturated solution of calcium sulphate (gypsum) would react upon the soluble salts of strontium so as to produce the celestite. The carbonate of strontium was not observed at the Woolmith quarry in association with the sulphate, there appearing to have been sufficient gypsum present to convert all of the original strontium salt into the more stable sulphate. At the Ida and Little Sink quarries only the carbonate was formed, while on the Lake Erie shore both the carbonate and sulphate are associated, indicating that the supply of dissolved gypsum was insufficient.

In the Plum Creek quarries, near Monroe, celestite may be observed undergoing alteration into strontianite, a rather unexpected change, the sulphate being regarded usually as the more stable form. However, a similar change may be produced in the laboratory by boiling the powdered sulphate with solutions of the alkaline carbonates; sodium, potassium or ammonium. It seems very probable that cold water, charged with one or more of the alkaline carbonates might, in the course of time, convert the outer portions of the crystallized sulphate into the carbonate.

§ 8. Gypsum.

Just referred to as probably having been active in the production of celestite is this calcium sulphate, which, although related to it in composition, is still readily distinguished from it by simple physical properties. Either in the form of gypsum ($CaSO_4+2H_2O$), or as the anhydrous variety (anhydrite, $CaSO_4$) this calcium sulphate is widely distributed through the Monroe beds of the county. As given in Chapter III, § 5, this sulphate was deposited directly from the waters of an inland sea, along with the calcium and magnesium carbonates which constitute the beds of dolomite. It would be formed anew wherever free sulphuric acid, derived from the decomposition of pyrite or marcasite, came into contact with calcium carbonate in solution. Calcium sulphate dissolves in 400 parts of water so that surface water, percolating through the dolomites containing gypsum or anhydrite, would take more or less of it into solution. Upon standing quietly in rock cavities and fissures, crystals of gypsum known as selenite, might form. Such crystals occur sparingly at the Woolmith quarry, but were not observed elsewhere. These are perfectly transparent flat crystals, without color and having a glassy to pearly luster. They split readily into thin plates, which may be easily bent without completely separating, but the thin plates are not elastic, as in the case of mica.

The cleavage in this one direction is very perfect. The streak is white and the specific gravity below the average, being 2.3. It is distinguished from all the minerals thus far described by its inferior hardness, since it is readily scratched with the finger-nail. No effervescence can be secured from it by the use of acid. Fine granular to compact masses of gypsum, variously colored from impurities, are known as "plaster" and are valuable for fertilizing purposes. When heated to a temperature of about 392°F. the water in chemical combination is driven off, the mineral crumbles to a white powder and is known as "plaster of Paris." By weight this water (H_2O) comprises 20.9% of the mineral, combined with 32.5% of lime (CaO) and 46.6% of sulphur trioxide (SO_3).

§ 9. Anhydrite.

In the preparation of the plaster of Paris if the gypsum is brought to a temperature of 400° to 650°F. not only is the water of crystallization driven off, but the calcium sulphate practically loses its power to again unite with it and "set." It has closely approached the condition of the anhydrous variety ($CaSO_4$), which is of common occurrence in nature and is known as anhydrite. As generally seen this is a compact or very fine granular translucent mass, of a pure white color and breaking with an uneven fracture. It is brittle and heavier and harder than gypsum. It cannot be scratched with the finger-nail, but is readily scratched with a knife point, giving a white powder. In well drillings it is frequently called "marble," but is easily distinguished from it by the action of the dilute acid. Anhydrite will slowly dissolve in hydrochloric acid, but gives no effervescence, while a small fragment of marble effervesces vigorously as it dissolves. This form of calcium sulphate contains 41.2% of lime and 58.8% of sulphur trioxide. It is less soluble in water than is the gypsum. The presence of anhydrite, or gypsum, in drillings, or dolomites, may be detected by boiling the powder for a short time in hydrochloric acid contained in a test-tube and then allowing the acid to cool. If calcium sulphate was present a mass of very slender needle like crystals will make their appearance. It is not definitely known why the sulphate should have been deposited from the evaporating inland sea in the anhyrous form. Ochsenius has explained it as due to the fact that when the hydrous sulphate (gypsum) is in solution in concentrated sea water with certain salts of potassium it exchanges part of its water for sulphate of potassium, forming polyhalite (KCl) and other salts which remain in solution in the bittern while anhydrite is deposited.*

§ 10. Epsomite.

When the free sulphuric acid of waters percolating through a bed of dolomite acts upon the dissolved calcium carbonate there is formed calcium sulphate as described in § 8 of this chapter. As might be expected this same acid would react similarly upon the magnesium carbonate of the dolomite and give rise to magnesium sulphate ($MgSo_4 + 7 H_2O$), or epsomite. This is so very soluble that ordinarily we should not expect it to be deposited, but it is a common ingredient of mineral waters. Sometimes it occurs as a delicate efflorescence over the surface of rocks in dry fissures, the galleries of mines and caves. In the Ida well (see Chapter III, § 8) a 100 foot layer of this substance was reported and a sample saved. The sample proved to be epsomite, but it is believed to have come from a cavity or fissure and not to represent the entire bed which was probably a dolomite rich in anhydrite. Epsomite is now on the market at 2½ cts. per pound by the barrel. It contains by weight 16.3% of magnesia (MgO), 32.5% of sulphur trioxide (SO_3) and 51.2% of water (H_2O). It occurs usually in elongated slender orthorhombic crystals, white in color, with a glassy to earthy luster, breaking with perfect to imperfect cleavage. It can be scratched with the finger-nail, (Hardness = 2½), giving a white powder. Its specific gravity is but 1.75 so that it appears very light. On account of its easy solubility it has a pronounced taste, which is salty to bitter. Upon being heated it gives off much acid water in which it liquefies.

---

*Quoted from Mich. Geol. Sur., Vol. V, Pt. II, p. xvii.

C. Chlorides.

§ 11. Halite.

Owing to the possibility of the occurrence of rock salt ($NaCl$) in the northeastern part of the county (see Ch. VIII, § 12), a description of this mineral is here inserted. The common form of crystal is the cube, parallel to the faces of which it breaks readily with very perfect cleavage. When pure it is colorless and transparent but it is frequently rendered translucent and of a variety of colors from impurities. It can be scratched with the finger-nail, with some difficulty, giving a white powder. When pure its specific gravity is 2.1, so that it appears light. The most characteristic property is its familiar saline taste, being readily dissolved in water. It gives no effervescence with the acid. In the blow-pipe flame it fuses and imparts an intense yellow color, owing to its sodium, which makes up 60.6% of the mineral, while the remaining 39.4% is chlorine. It occurs in solid beds in the earth only where the subterranean waters have not had free access to it. It is believed to have been formed through the concentration of the waters of an inland sea.*

---

*See Chapter III, 5; also Geol. Sur. of Mich., Vol. V, Part II, pp. ix to xix.

D. Sulphur and Sulphides.

§ 12. Sulphur.

Closely associated with the celestite and calcite crystals at the Woolmith quarry are beautiful crystalline masses of brilliant yellow sulphur, contrasting gorgeously with the blue of the celestite and the creamy white calcite. Attention was first called to this occurence of native sulphur by the writer in 1895.*

The sulphur is confined mainly to the ellipsoidal cavities in a soft, open bed of dark brown dolomite from one to three feet thick. These cavities vary in size from a fraction of an inch to three feet in their greatest horizontal diameter. Some of these cavities are completely filled with the sulphur, which at times shows crystal faces, but generally the sulphur shows only the rough conchoidal fracture characteristic of such crystalline masses. More frequently the cavity has a lining of celestite and calcite and only the central portion contains the sulphur, showing that its deposition began later than that of these two minerals. It was estimated by the foreman at the time of the survey, four years ago, that between 400 and 500 barrels had been removed, most of which was carried away by visitors. The present market value of such sulphur is 2½ cents per pound. This mineral is very easily distinguished from all others by its brilliant yellow, its resinous luster and conchoidal fracture. It is quite brittle, can be scratched with the finger-nail, has a specific gravity of but 2 and is translucent. It melts readily and burns with a blue flame emitting irritating odors of sulphuric dioxide (SO_2). It is insoluble in water and is not affected by acids. When the deposits were first examined by the writer in 1895 there entered the quarry from the "sulphur bed" a stream of water charged with hydrogen sulphide gas (H_2S). As the water trickled down the face of the quarry wall and flowed over the bottom there was deposited a mealy white precipitate of sulphur, resulting from the decomposition of this gas. Where this deposit was longest exposed it showed a slight yellow color. From the cavities of the dolomite specimens of whitish yellow sulphur were collected, having the same mealy appearance, but containing throughout small irregular masses in the crystalline condition. There is no room for doubt then that the sulphur has resulted from the decomposition of hydrogen sulphide gas, introduced through the agency of percolating water, and that it has gradually passed from the mealy to the crystalline condition. The gas has been formed in the rocks through the decomposition of the next two minerals to be described.

---

*American Journal of Science, Vol. L, Third Series, pp. 246-248; also in a paper presented to the Michigan Academy of Science, Lansing, December, 1895.

§ 13. Pyrite and marcasite.

These are two minerals which have the same chemical composition (FeS_2), being compounds of iron and sulphur. They contain by weight 53.4% of sulphur and 46.6% of iron. They are not often seen at the surface, but are abundant enough in the rock strata to give character to the spring and well water and to be indirectly responsible for the formation of a number of the minerals described in this chapter. They each have a brassy luster and color, a specific gravity approaching 5 and are hard enough to make a scratch upon glass. They are brittle, break with an uneven fracture, are opaque and have a black streak. When heated sufficiently they are decomposed, the sulphur burns with its characteristic blue flame and leaves behind a dark mass which is now magnetic, owing to the free iron. The pyrite is generally found in beautifully perfect cubes of various sizes, having a golden color and luster, which causes it frequently to be mistaken for gold. In the dolomite of the Plum Creek quarries seams and incrustations of crystallized pyrite occur, in tarnished condition. The crystals are very small, giving the mineral a fine granular appearance, and are mainly octahedrons. This is the only locality at which pyrite was found. The marcasite is of a whiter yellow, does not occur in cubes, but usually in flattened concretions showing radially fibrous structure, and is more subject to decomposition than the pyrite. The formation of these two minerals through the agency of organic matter and oxide of iron was explained in Chapter II, § 11. When either of these minerals is in contact with water for a sufficient length of time, double decomposition takes place. The sulphur unites with hydrogen of the water to form hydrogen sulphide gas (H_2S), which is readily held in solution by the underground water and gives rise to "sulphur" springs and wells. The iron of the pyrite, or marcasite, is readily oxidized and if carbon dioxide be present will be converted into iron carbonate ($FeCO_3$), taken into solution and will impregnate the water with iron, forming "chalybeate springs or wells" (chapter VIII, § 10). The hydrogen sulphide itself may unite with oxygen to form sulphuric acid (H_2SO_4), which may unite with iron, calcium or magnesium to form the series of sulphates found in the natural waters. Pyrite and marcasite are very undesirable ingredients of building stone because of their tendency to decompose, whereby the stone itself is disintegrated and discolored through the oxidation of the iron left behind.

E. Oxides.

§ 14. Bog iron ore (limonite).

Before the rich deposits of iron ore were located in the Lake Superior region and Missouri this impure form of iron oxide was eagerly sought. Hubbard in his original survey of the county located deposits in Secs. 19 and 25, of Summerfield township and called attention to indications in Sec. 3 (T. 9 S., R. 7 E.) of Bedford, and also in London.[*]

During the present survey other records were obtained of similar deposits. In section 23 of Milan (N. W. ¼, S. E. ¼) N. D. Baird struck bog ore at a depth of five feet while ditching. It is said to occur also one mile south of Petersburg upon the place of Enos Plomodore (S. W. ¼, N. W. ¼, Sec. 10). In the N. W. ¼, N. W. ¼, Sec. 26 of Bedford, bog ore occurs along a ditch for a distance of ten rods. This mineral occurs in marshes, where it is now forming, and in the beds of former swamps now drained and under cultivation, in beds of varying thickness. Irregular rusty lumps are found in the soil, having a dull earthy luster and without crystalline structure. Their high specific gravity (3.6 to 4) at once distinguishes them from irregular lumps of tufa or clay. The mineral breaks with an irregular fracture, is opaque, can be scratched with difficulty with a knife-point and gives a yellowish brown powder. It is an oxide of iron in combination with water, its formula being $2Fe_2O_3+3H_2O$. When pure it contains 59.8% of iron, 25.7% of oxygen, and 14.5% of water. When mixed with considerable clay it is known as "yellow ochre" and has been used as a paint. Upon the application of sufficient heat the water of crystallization is driven off and the oxide is converted into the red oxide known as hematite (Fe_2O_3). This also exists in a soft earthy form known as "red ochre," a bed of which three rods square, and one to two feet thick, was located in Sec. 21 of Bedford township, by Hubbard.[†]

---

[*] Second Annual Report State Geologist, 1839, H. R. No. 23, page 112.

[†] The first volume of the American Journal of Science in 1819 announced the "Discovery of American Cinnabar and Native Lead." (pp. 433-4.) A portion of a letter from J. L. Comstock, of Hartford, Connecticut, was published by the editor, which contained an extract from a letter written by B. F. Stickney, Indian Agent

When clay of a brown or yellow color from the presence of the hydrous oxide is burned, as in the manufacture of brick and tile, the conversion to the red oxide takes place in the furnace and a total change in color results. The iron for the formation of beds of bog ore is derived from the soil of the area which is drained into the marsh. It is introduced into the soil from the iron bearing minerals which have contributed to its formation, as hornblende, pyroxene, black mica, pyrite, siderite, etc., of the crystalline rocks. Upon the decomposition of these and other minerals iron is liberated which soon unites with the oxygen of the air forming generally the yellow hydrous oxide. In this form it is abundant in the soil and is insoluble, but must be transported before any beds can be formed. This is accomplished through the agency of decaying organic matter in the soil. The carbon of this organic matter has a stronger affinity for oxygen than has the iron, and some of the oxygen is torn from the iron oxide forming ferrous oxide (FeO). The carbon dioxide (CO_2) formed in consequence may unite with the ferrous oxide and form ferrous carbonate ($FeCO_3$). This carbonate is somewhat soluble in water containing carbon dioxide and is leached from the soils and transported by the streams to the swamps. Upon standing the carbon dioxide of the carbonate is exchanged for oxygen of the air with the formation of the oxide and the liberation of the CO_2. The oxide being insoluble must be precipitated and usually goes down as the hydrous form, that is, the bog ore variety. Beds rarely exceed one to two feet in thickness. From this method of formation it is apparent that the ore will be mixed with sand, clay and other impurities. For this reason and the manner of occurrence this ore has no commercial value at present. Shaler has suggested that as top dressing this ore adds binding qualities to limestone used in the construction of stone roads.

§ 15. Crystallized quartz.

The Sylvania sandstone has been described as consisting of countless millions of quartz crystals, each a hexagonal prism terminated

---

at Fort Wayne. The latter says, "I have found a black and garnet colored sand, in great abundance on the shore of Lakes Erie and Michigan, this is sulphuret of mercury, and yields about sixty per cent. It is so easy to be obtained, and is so convenient a form for distillation, that it must become an important article of commerce." In the second volume of the same journal (p. 170) the editor publishes a letter direct from Mr. Stickney, dated "Port Lawrence, Michigan Territory, Mouth of the Miami of the Lakes, June 17th, 1819," in which he says, "From the mouth of the Vermillion, round the whole shore of the western end of Lake Erie, on the shores of the Detroit river, Lakes St. Clair, Huron, and Michigan, the banks are streaked with small reefs of this black and red sand of cinnabar. The whole body of the soil is interspersed with this sand through the whole of this extensive district of country." The editor announced that a sample of the sand, enclosed in a letter had been lost. In his Catalogue of American Minerals, published in Boston, 1825, by Dr. Samuel Robinson this occurrence of cinnabar is noted (page 239). The red and black sand referred to must have consisted of oxides of iron.

by one or two hexagonal pyramids. The formation of these crystals through the secondary enlargement of rounded sand grains has been presented in Chapter III, § 6.

Water saturated with silica (SiO_2) and standing quietly in fissures and cavities sometimes forms an incrustation of quartz crystals. If no impurities are present the crystals are transparent and without color being known as "rock crystal." Limited quantities of this occur at the Navarre quarries on Plum Creek. When colored purple the quartz is called "amethyst" and this variety was observed at Brest by Dr. Winchell and is reported by Dana as occurring here and at Point aux Peaux and Stony Point. Quartz is readily distinguished from all the other minerals described by its simple physical properties. The form of the crystal is entirely characteristic when this can be made out, the hexagonal prism terminated with the hexagonal pyramid. It has a glassy luster and has no plane cleavage faces, but a conchoidal fracture. Its specific gravity is 2 2-3. It cannot be scratched with a knife or file and scratches glass very easily. It is insoluble in pure water, is unaffected by the ordinary acids and is infusible before the blowpipe. Heated with soda, however, it readily melts and forms glass. It consists, when pure, of 46.7% of silicon and 53.3% of oxygen.

§ 16. Chert.

This is a variety of uncrystallized or rather cryptocrystalline quartz (SiO_2) commonly known as "flint." It is, however, too impure for flint, since it contains a considerable percentage of calcium carbonate. From its resemblance to horn it has been called "hornstone," and owing to its abundance in our Dundee formation gave to it the name of Corniferous (*cornu*, a horn). As found in Monroe county its color is drab to brown, with a dull to subresinous luster. It is opaque to sub-translucent and is very brittle, breaking with a coarse conchoidal fracture and giving sharp edges. It readily strikes fire with steel and scratches glass with about the same ease as crystallized quartz. Its specific gravity is not perceptibly different. It occurs in the Monroe beds and the Dundee formation in seams and crevices, in irregular nodules, and as thin beds between the strata of the dolomite and limestone as previously described. In the quarries most of it is seen on the Macon and at Dundee, where it forms thin beds. It frequently encloses fossils in silicified condition, in the cavities of which the silica has sometimes crystallized, giving a thin layer of minute crystals suggestive of frost and known as "drusy quartz." The formation of this chert and the origin of its silica have been discussed in Chapter II, § 22. It is too impure for the manufacture of glass, for which flint is used, and its brittleness and lack of binding qualities unfit it for macadamizing purposes. Its hardness, manner of breaking and inertness to the weather made of it a most useful mineral for primitive man. From it he made his spear and arrow-points with which to capture game, the implement with which to prepare, and the spark of fire with which to cook such game. Quarries of a good grade of chert were of more value to him than the richest gold mines of the Klondike or the diamond fields of Kimberly.

F. *Phosphates.*

§ 17. Apatite.

This is a mineral reported by Winchell and Dana as occurring at Brest, Point aux Peaux and Stony Point, but a careful search failed to reveal any of it at the present time. It is a phosphate of calcium, with the formula $(CaF)\ Ca_4\ P_3\ O_{12}$, occurring sometimes in limestones, but more commonly in the crystalline rocks. It contains of P_2O_5 42.3%, of lime (CaO) 55.5%, and of fluorine 3.8 %. When properly prepared it is valuable for fertilizing purposes since it supplies the soil with both lime and phosphorus. Its common mode of occurrence is in the form of elongated hexagonal prisms, of a brown or green color. Its luster varies from glassy to resinous, the mineral looking as though it were slightly oily. It is subtranslucent to opaque, is quite brittle and shows only imperfect cleavage across the prisms. Its specific gravity is a little above the average of rocks (3.2), while its hardness permits of its being scratched, with some difficulty, with a knife-point. It gives no effervescence with the acids. This assemblage of characters readily distinguishes apatite from any other mineral encountered in the county.

G. *Hydrocarbons.*

§ 18. Asphaltum.

Black, amorphous carbonaceous matter has been mentioned as occurring at various quarries, filling seams and crevices in the dolomites and limestones. Thin layers, more or less continuous, frequently occur between the beds, rarely attaining a thickness of one-quarter inch. Certain beds at the Woolmith quarry are impregnated with this substance to such an extent that the stone is considerably darkened by it and Mr. G. F. Smith has suggested its use for asphalt pavements, believing that by grinding and heating there would be found sufficient asphaltum to bind together the fragments. As seen in the county, both at the quarries and in the well drillings, the substance is always very impure. If held in a flame it burns for a short time, giving a bright yellow flame and oily odor, but does not perceptibly diminish in bulk. There is usually not sufficient carbonaceous matter present to continue the combustion after the fragment is withdrawn from the flame. When pure, asphaltum is very brittle, of a jet black color and pitchy luster, breaking with a coarse conchoidal fracture. It is soft and very light, its specific gravity ranging from 1 to 1.8. It readily melts and burns with a bright yellow, smoky flame. It is more or less soluble in turpentine, ether and alcohol, but not in water. It has formed where now found by the accumulation of rock oil, which has gradually lost its more fluid constituents and hardened. It is thus of organic origin, has no definite composition, consisting mainly of carbon, hydrogen and oxygen, and cannot be regarded as a true mineral.

H: Key to Minerals.

§ 19.

The following simple key will enable those interested to readily determine the minerals of the county which are encountered in the quarries and well drillings. It will be of no service in identifying the ingredients of the common field boulders. The acid referred to is hydrochloric acid and is prepared by taking a small quantity of commercial strength and adding four times its volume of pure water. In using this a drop of the cold acid is first applied to the solid mineral. If the action is not vigorous the mineral may be reduced to powder at one place and the acid applied, or a fragment may be placed in acid in a test-tube and then heated. After the mineral has been traced, its description, as given in this chapter, should be carefully reviewed for the purpose of verification.

TABLE XIV.—KEY TO THE MINERALS OF MONROE COUNTY.

Effervesces with dilute acid.	Incoherent.				White and mealy looking, associated with muck. Action with acid vigorous.	Marl.
	Coherent, in lumps or crystals.	Heavy.			Occurs in irregular lumps, covered with fine crystal points. Action with acid is vigorous: colors flame an intense red.	Strontianite.
		Medium.	Acid action on solid mineral is	Vigorous.	Occurs in sharp pointed crystals, or breaks into rhombohedrons. Does not crumble on being intensely heated.	Calcite.
					Occurs in six-sided prisms, or radiating groups of needle-like crystals. Crumbles on being heated.	Aragonite.
				Slight.	Action is increased by powdering the mineral.	Dolomite.
		Light.			Irregular brownish lumps of a loose, open structure. Action with acid vigorous.	Tufa.
Does not effervesce with dilute acid.	Scratched with finger-nail.	Easily.	Not crystaline. Occurs in irregular, earthy masses.		Rusty yellow to brown.	Yellow ochre.
					Cherry red.	Red ochre.
			Crystalline.		Flat transparent crystals, separable into thin, flexible plates.	Selenite.
		With some difficulty.	Soluble in water, will not burn.		Small white needle crystals, bitter taste.	Epsomite.
					Breaks into cubes, salty taste.	Halite.
			Insoluble in water, will burn.		Color yellow, burns with blue flame.	Sulphur.
					Color black, burns with yellow flame.	Asphaltum.
	Not scratched with finger-nail.	Luster glassy.	Will not scratch glass.		Very heavy, perfect cleavage, flat tabular crystals.	Celestite.
					Moderately heavy, imperfect cleavage, six-sided prisms.	Apatite.
			Will scratch glass easily.		Average specific gravity, no cleavage, conchoidal fracture. Occurs in six-sided prisms with pyramids.	Quartz.
		Luster metallic.			Granular or in isolated cubes or octahedra, golden yellow color, slightly tarnished.	Pyrite.
					Flattened concretions, radially fibrous structure, silvery yellow, tarnished.	Marcasite.
		Luster dull.	Very heavy.		Rusty irregular lumps, generally loose in the soil.	Bog iron ore.
			Medium weight.		Drab or brown, conchoidal fracture, scratches glass easily.	Chert.
					Pure white, uneven fracture, will not scratch glass.	Anhydrite.

CHAPTER X.

FOSSILS OF MONROE COUNTY.

§ 1. General nature of fossils.

Embedded in the rocks which have been described, and imprinted upon the surfaces of the strata are the remains of former plant and animal life. From their resemblance to forms still in existence we know that they lived in the waters of an ocean charged with salt. From a study of the deposits which have been superposed, here and elsewhere, upon these strata we are forced to the conclusion that this ocean existed in Michigan so long ago that the time can be estimated only in millions of years. Nowhere in the county, or adjoining regions, have there been found embedded in the rocks any trace of forms higher than the lowest order of fishes. When we consider the advance which has been made biologically since that time we are still better able to grant to these fossils the respect which is accorded great age. When such objects first began to attract attention during the 15th and 16th centuries they were regarded as "sports of nature," as though produced through Nature's effort at self amusement. By some writers they were thought to be due to the "influence of the stars," and by others to have resulted from the fermentation of certain fatty matter in the earth through the agency of heat. Early in the 16th century Fracastoro and Leonardo da Vinci declared that they represented the remains of organisms which had once lived where they are now found, a view that was savagely combatted for 200 years. As this simple truth finally prevailed over prejudice and superstition the question arose as to the time of their destruction, it being assumed that their death was simultaneous and produced by some widespread natural catastrophe. For a long time and by many the Noachian deluge was regarded as the cause of this universal destruction of life, of marine forms as well as those which lived upon the land. During the 18th century the discussions covered the method of extinction and entombment, the formation and displacement of the rocks containing them, the succession of forms and their relation to living species. By the middle of the century it had been shown by Marsilli, Spada and Schiavo that fossils are not scattered at random through the rocks, but that there is an orderly succession. By the close of the century this truth had borne fruit. William Smith, an English engineer, suggested their use in recognizing and correlating strata, since beds of the same age should contain the same assemblage of fossils. During the century just closing thousands of forms have been described and figured, their groupings in the strata investigated, and the solution of the problems of development undertaken. From such study beds of economic importance may be located in the geological series and the physical and biological history of the earth deciphered.

By Lyell a fossil was defined as any body, or the traces of the existence of any body, whether animal or vegetable, which has been buried in the earth by natural causes. The cast or mould of any organism whatever, the imprint of a leaf or the foot print of an animal would thus come within the definition. So also would the body of a sheep buried by yesterday's land slide, but probably would not have been regarded as a fossil by Lyell himself. It is now generally understood that the form, in order to be considered a true fossil, must have lived during a previous geological epoch.

§ 2. Conditions of preservation.

With reference to their manner of preservation fossils may be separated into four classes. First, those in which the organic matter itself has been preserved as in the case of some of the plant remains to be described. Here the carbonaceous matter of the tissue is still in existence and makes up the fossil, although it has been mineralized. Rock oil represents such preserved organic matter which has become separated from the organisms of which it at one time constituted a part. In this same class should be placed bones, shells, corals, etc., which still retain the matter of which they were originally formed. In a second class of fossils this original matter has been replaced, particle by particle, by other mineral matter giving rise to a "petrifaction." The replacing mineral is most commonly calcite or silica, but may be pyrite, sulphur, iron oxide, etc. Very frequently, as in the case of silicified wood, the minute details of even the microscopic structure are most perfectly reproduced. In still a third class of fossils the organism itself, or some part of it, has left its impress upon a soft mass capable of retaining the form. After hardening there is thus produced a mould of the original object. Such moulds of shells are quite common in the dolomites and occasionally a coral, or crustacean, is similarly preserved. Imprints of leaves, burrows and channels, footprints, etc., belong to this class. Finally, upon the withdrawal of the organism, or its removal by decay or solution, soft mineral matter may settle into the mould and form a cast. The most common form of cast is that of the entire exterior, but internal casts of shells are also not uncommon in the county. These are produced by the fine sedimentary material working its way into the internal cavity and there hardening. When the shell is dissolved away by percolating water a space is left between the mould and the internal cast. This occasionally becomes filled with sediment, sometimes with crystalline material and a cast of the shell itself is formed, which very much resembles a true petrifaction, but differs from it in not showing any of the real shell structure.

§ 3. Fossils of the Monroe beds.

The beds of dolomite are in general quite poor in fossils, but at certain horizons and in certain localities moulds and casts of brachiopods and gasteropods are abundant, crinoids, corals and bryozoan remains are found occasionally and lamellibranchs rarely. Worms, cephalopods and crustaceans are the only other animal groups that are known to be represented in this series of beds. There is nothing here to indicate that fish had yet come into existence, not a tooth, scale, plate or spine having yet been found. In nearly all cases the shell substance has been dissolved and nothing has been deposited in its place, so that the identifications have to be made upon the moulds, imprints, external and internal casts. A large number of such fragments were collected which are unidentifiable, either because of their state of preservation or because they represent species not yet described. The writer feels reasonably certain of the list below enumerated. A study was made of the fossil contents of the Monroe beds by Rominger and reported upon in 1876.* From these same beds in western Ohio, Whitfield identified and described a number of forms in a paper read before the New York Academy of Science in 1890.†

---

*Michigan Geological Survey, Vol. III, Pt. I, pp. 31 to 34.

†Description of Fossils from the Palæozoic Rocks of Ohio. Ann. N. Y. Acad. of Science, 1890: pp. 505 to 622. Also Geol. Surv. of Ohio, Vol. VII, pp. 407 to 493. Plate V accompanying this paper is reproduced as plate XVII of this report through the kindness of Prof. Whitfied and the Ohio Survey, although it contains some forms not yet discovered in the county.

SPIRIFER VANUXEMI, Hall. Palæontology of New York, Vol. III, 1859; p. 198, plate VIII, figs. 17 to 23.

Orthis plicata, Vanuxem. Geol. Rep. Third District of New York, 1842; p. 112, fig. 1.

A few specimens of this species were found in the beds about Monroe, but they are not common. Adult forms of the type figured on plate XVII, figures 4 and 5, occur and also immature specimens similar to those drawn and described by Hall.

MERISTELLA LÆVIS, Vanuxem, sp.

Atrypa lævis, Vanuxem. Geol. Rep. Third District of New York, 1842; p. 120, fig. 2.

Merista lævis, Hall. Palæontology of New York, Vol. III, 1859; pp. 247-8, plate XXXIX, figs. 1 to 4.

Meristella lævis, Hall. Thirteenth Ann. Rep. of Regents on the N. Y. State Cabinet, 1860; p. 75.

Cf. *Whitfieldella lævis?*, Grabau. Bull. Geol. Soc., Am. 1900, Vol. XI, p. 369.

This is the most common and most widely distributed fossil in the county, being seen at nearly all the localities where the beds of dolomite are exposed. Its general form is shown in figures 6 and 7 of plate XVII.

MERISTELLA BELLA, Hall. Thirteenth Ann. Rep. of the Regents on the N. Y. State Cabinet, 1860; p. 75.

Merista bella, Hall. Palæontology of New York, Vol. III, 1859; p. 248, plate XL, fig. 1, a-p.

This form, which much resembles the preceding and is found in association with it, is figured on plate XVII, figures 8, 9, and 10. The general outline is seen to differ from *Meristella lævis*, and each valve possesses a sinus the meeting of which give a more emarginate character to the front.

NUCLEOSPIRA ROTUNDATA, Whitfield. Ann. N. Y. Academy of Science, 1882; p. 194.

Se plate XVII, figures 11 to 14. The best preserved specimens of this species were collected from the beds of the Woolmith quarry where they are associated with Meristella.

RETZIA FORMOSA. Hall, sp.

Waldheimia formosa, Hall. Tenth Ann. Rep. of the Regents on the New York State Cabinet, 1857; p. 88.

Trematospira formosa, Hall. Palæontology of New York, Vol. III, 1859; pp. 215-216, plate XXXVI, figs. 2, a-u.

Rhynchospira formosa, Hall. Palæontology of New York, Vol. III, 1859; p. 485, plate XCV A, figs. 7-11.

This beautiful little shell is shown on plate XVII, figures 15 and 16. Quite perfect moulds are sparingly found, apparently more frequently at the Little Sink and Little Lake quarries. These specimens agree with those described from Ohio in being smaller than those from New York, figured by Hall.

PENTAMERUS GALEATUS, Dalman, sp.

Atrypa galeatus, Dalman. Vet. Acad. Handl., 1827; p. 130.

Pentamerus galeatus, Hall. Palæontology of New York, Vol. III, 1859; pp. 257-9, plate XLVI, figs. 1, a-z; plate XLVII, figs. 1, a-m.

Gypidula galeata.

Fragments of this large brachiopod are found about Monroe, one quite complete ventral valve having been secured, from which the identification was made.

PENTAMERUS PES-OVIS. Whitfield. Ann. N. Y. Acad. Science, 1882; p. 195.

This form was named because of the resemblance of its internal casts to sheeps' feet. See plate XVII, figures 18-22. These casts are in the dolomite about Monroe.

GONIOPHORA DUBIA, Hall, sp.

Modiolopsis dubius, Hall. Palæontology of New York, Vol. III, 1859; p. 264, plate XLIX, figs. a-e.

Goniophora dubia, Whitfield. Geol. Sur. of Ohio, Vol. VII, 1893; pp. 415-16, plate I, figs. 24-26.

Specimens of lamellibranchs are very infrequently met with in the Monroe beds. A number of well preserved forms of this species, however, were collected from the Plum Creek quarries. They are shown on plate XVII, figures 24-26.

PTERINEA AVICULOIDEA, Hall, sp.

Megambonia aviculoidea, Hall. Palæontology of New York, Vol. III, 1859; pp. 274-5, plate XLIX, figs. 7 and 8; plate XLIX A, fig. 8.

Pterinea aviculoidea, Whitfield. Geol. Rep. of Wis., Vol. IV; p. 322, plate XXIV, figs. 6 and 7.

The internal cast of the left valve of a large specimen of this, or a closely related species, was found in Daniels' quarry at the head of Ottawa Lake. The species is reported from the county by Rominger and from the Ohio beds by Whitfield. See plate XVII, fig. 23.

LEPERDITIA ALTA, Conrad, sp.

Cytherina alta, Vanuxem. Geol. Report of the Third Dist. N. Y., 1842; p. 112, fig. 6.

Leperditia alta, Jones. Ann. and Mag. of Nat. Hist., Vol. XVII, second series, p. 88.

This peculiar crustacean is shown in side view on plate XVII, figure 27. It is especially characteristic of the Waterlime division of the Lower Helderberg. It is of rare occurrence in the county but was found around Little Lake, in Bedford township. There occurs in the same vicinity a minute Leperditia of the same general form as the above but with a length of only .05 to .06 of an inch. The prominence of the eye tubercles indicates that it is distinct from L. alta and no intermediate forms were observed.

SPIRORBIS LAXUS, Hall. Palæontology of New York, Vol. III, 1859; p. 349, plate LIV, figs. 18, a-e.

The coiled tubes of very small marine worms are abundant about Newport and Monroe and at the Little Sink and Little Lake quarries. They appear to be identical with Hall's forms from the Lower Helderberg of New York. The tubes are circular in cross section, show from 1½ to 3 coils, with a diameter of .02 to .04 of an inch. Usually nothing but the minute cavity remains, but occasionally a cast is found which shows 11 to 12 annular ridges in the last half whorl. Sometimes a considerable part of the last whorl is free from the remainder of the coil and irregularly extended. The Little Sink specimens are coarser than those found about Monroe and may represent another variety. Associated with them are tortuous vertical channels, which represent the burrows or tubes of larger worms. to which the generic name *Scolithus* has been applied.

In addition to the above identifiable species a large number of fragments were collected which cannot be satisfactorily specifically determined. These include Conularia, Tentaculites, Strophodonta, Orthis, Spirifer, Conocardium. Platyceras and numerous other gasteropods, lamellibranchs, trilobites, crinoids, cyathophylloid and favositoid corals.

Several types of plant fossils occur within the limits of the county. From what was said concerning the formation of the oölite granules and the associated structure in Chapter III, § 7, it is evident that these must be regarded as fossils. Under the same head would come the vertical channels found in one of the silicious dolomites at the Woolmith quarry, Chapter IV, § 4. These are supposed to represent the casts of marine plant stems about which the sandy. dolomitic slime settled and partially hardened. Upon the upper surfaces of certain ledges at Newport, Plum Creek and Little Lake quarries carbonized plant remains occur in abundance. The stems of one form are straight. unbranched and flattened and appear to be longitudinally creased by about eight furrows. The diameter of the flattened stems change but little in an inch or two and equal .06 to .07 of an inch. There is evidence of irregular jointing. Associated with this form is a more delicate variety which branches dichotomously and has a breadth of but .01 of an inch. A still coarser and less flattened type of stem is seen about Newport, hava breadth of .10 to .13 of an inch. These all very probably are remains of marine algæ. Of these remains which Rominger found at Newport he says the following:*

> "The vegetable remains are of various kinds. Some are band-like. compressed stems, which sometimes bifurcate, and are of a jointed structure. On certain portions of these stems, annular cicatrices are disposed in remote rows, in shape resembling the pores of the tube of Favosites. Another kind of stem is narrower, more remotely jointed, and each joint is surrounded by a verticil of long, narrow leaves."

§ 4. Fossils of the Dundee formation.

The limestones exposed in the Dundee and Macon quarries are exceedingly rich in fossils. Upon weathered surfaces, under the magnifier, they are seen to consist of one mass of minute fragments in which, here and there, entire forms are embedded. The same species occur here as in the Trenton quarries where the opportunities for collecting are far better. Therefore detailed description of this fauna may be left to the Wayne county report. Upon the other hand all the forms found at Trenton are liable to be encountered in the Monroe county exposures. An extensive collection was made from the Sibley quarry, just north of Trenton, but there has not been time for its study. The following species were collected from this locality by Dr. Rominger:

---

*Mich. Geol. Sur., Vol. III. part I, p. 32.

Atrypa reticularis, Linnæus, sp.
Spirifer gregarius, Clapp.
Spirifer acuminatus, Conrad.
Orthis Livia, Billings.
Strophodonta concava, Hall, sp.
Strophodonta perplana, Conrad, sp.
Paracyclas elliptica, Hall.
Conocardium subtrigonale, D'Orbiguy.
Pleuronotus Decewi, Billings, sp.
Phacops bufo, Green, sp.
Proetus crassimarginatus, Hall, sp.
Dalmania selenurus, Eaton, sp.
Stromatopora textilis, Rominger.
Stictopora Gilberti, Meek.
Zaphrentis prolifica, Billings.
Zaphrentis gigantea, Lesneur.
Heliophyllum Halli, Edwards and Haime.
Heliophyllum corniculum, Lesueur, sp.
Favosites turbinatus, Billings.
Favosites hemisphericus, Troosy, sp.

In addition to the above species the following genera were represented by unidentified species. Fenestella, Polypora, Orthoceras, Gomphoceras, Gyroceras and Nautilus. Spines, plates, bones and teeth of sharks are found, most of them belonging to Onychodus sigmoides (Newberry), of the Upper Helderberg of Ohio.

In regard to the correlation of the fauna of the upper and lower Helderberg, Dundee and Monroe beds, reference should be made to Schuchert's paper already cited.*

---

*Bull. Geol. Soc. of Amer. pp. 241 to 332. See also paper by A. W. Grabau in the same volume, pp. 347-376, on the Siluro-Devonian contact in Erie county, New York. It is only fair to Prof. Sherzer to say that the important papers by Clarke and Schuchert, Williams, and Grabau referred to, have appeared during the proof reading, and the foot notes referring to the same and some slight changes in the text have been made largely by myself. While Prof. Sherzer has had a chance to see most of them, they may not be such as his deliberate judgment would approve, and in any case he would doubtless give these papers more worthy and ample treatment did time permit. It will appear clear upon careful reading of them that Clarke and Schuchert have excluded from the (Lower) Helderberg the Tentaculite

It seems clear that the Dundee fauna corresponds to that of the upper Helderberg, the Becraft limestone (Upper Pentamerus) of Darton and Schuchert, and that the bulk of the Monroe beds, especially those below the Sylvania sandstone have a Silurian fauna akin to that of the Manlius limestone or Waterlime. So far as yet appears there is no reason for cutting off any of the Monroe beds faunally from their lithological representatives, and considering them Devonian.

---

or Manlius limestone, which was considered originally its lowest member. In the western part of New York, Ohio and Monroe county, Michigan, the beds just above are wanting, and the unconformity which Grabau has pointed out exists. Hence naturally the Manlius limestone fauna has come to be regarded as typical Lower Helderberg in the region of the Great Lakes. This is regarded by all as Silurian. Whether the balance of the Lower Helderberg should be so regarded we have no occasion to decide. It may be noted, however, that if Hunt is right as to the intercalation of Corniferous in the Salina (p. 52), we must either include all the Salina as Devonian, or give up the "Devonian facies" as a criterion.—L.

GENERAL INDEX.

A.

Acicular structure.............. 86
Adrian.............32, 38, 133, 134, 136
Alcona moraine.............140, 143
Algæ.........................66, 226
Algonkian Indians.............. 6
Algonquin Lake................. 144
Alluvium 12, 110, 111
Alpena, Thickness of Hamilton at. 32
Alumina. See CLAY and ANALYSES also................. 26
Altitudes 106
  of R. R. stations........... 108
  of beach lines.............. 143
  of Sylvania sandstone....... 54
Amethyst....................... 216
Ammonia, source of, in soil........ 166
Analyses, and composition of—
  cement rocks...........181, 182
  farm products.............. 159
  limestone and dolomite 76, 87, 92, 95, 150, 176, 178
  minerals.............204 to 217
  sandstone.................. 57
  soils........151, 152, 155, 156, 163
  sugar beet limestone........ 179
  water...................... 201
Anhydrite 52, 67, 68, 69, 73, 209, 210, 219
Ann Arbor..... ....26, 32, 33
Ann Arbor R. R. (Toledo & Ann Arbor)..75, 87, 88, 105, 122, 136
Ants, work of.................... 170
Apatite 219
Appalachian uplift............... 137
Aragonite...............204, 205, 219
Argillaceous matter. See CLAY.. 40
Arkona Lake and Beach, 114, 138, 139, 142, 143, 153, 154, 195
Artesian wells................ ... 194
Asam, Joseph (claim 422)......192, 200
Ash Township (T. 5 S., R. 9 E.) 44, 54, 161 162
  Section 6.................. 195
  Section 8.................. 91
  Section 13................. 56
  Section 20................. 19
  Section 29................5, 56
  Section 30................. 127
  Section 32................. 56
  Section 34 93
Ash tree.....................164, 165
Aspen.......................... 165
Asphaltum. See CARBONACEOUS and BITUMINOUS matter.. 219
Atrypa reticularis................ 227
Azalia 108, 122

B.

Balsam tree..................... 165
"Bastard" limestone..........61, 100
  See OÖLITE.
Battle of the Raisin.............. 6
Bay Creek...............9, 98, 100, 114
Beach levels..................... 109
  See also ARKONA, BELMORE, FOREST, GRASSMERE, LEIPSIC.
Beans production of.............. 163
Becraft limestone..............37, 228
Bedford Township (T. 8 and 9 S. R. 7 E)....14, 18, 141, 161, 162, 163, 196, 225
  Section 1.................. 98
  Section 2.................. 127
  Section 3.................. 214
  Section 4.................. 20

Bedford Township
  Section 10 ....61, 99
  Section 12.... 98
  Section 15....98, 99, 116
  Section 16.... 99
  Section 21....99, 214
  Section 29.... 70
Bedrock.... 25
Beech 164, 165
Beet sugar 163, 178, 179
Bell, Robert.... 192
Bell, William.... 197
Bellaire.... 186
Belmore Beach.... 119, 136, 137, 138, 154, 196
Berlin Township (T. 5 and 6 S. R. 9, 10 and 11 E.)....18, 53, 67, 92, 161, 162, 196
  Section 1.... 56, 67, 92
  Section 7....56, 195
  Section 8....55, 56
  Section 10.... 123
  Section 15.... 201
  Section 17.... 56
  Section 18.... 56
  Section 19....56, 214
  Section 23.... 113
  Section 26.... 56
  Section 33.... 23, 70 152, 201
Big Sink 115, 116
Bitternut.... 165
Birmingham, Wayne Co.... 135
Bischof.... 51
Bituminous matter. See ASPHALT and CARBONACEOUS matter....14, 29, 35, 46
Black River.... 135
Black shale. See SAINT CLAIR shale.... 25
Blissfield.... 139
Blonch, Thomas.... 98
Bog iron ore.... 24, 214, 215, 219
Bond, Oliver S..... 70
Boudie, A..... 201
Borrow, J..... 56
Boyer, Edward D..... 180
Brachiopods. See also names of genera.... 56
Brancheau.... 92
Branch, Harmon.... 197
Branner, J. C.....58, 170
Brazil.... 170
Brecciated limestone....14, 47, 63, 94
Brest...9, 10, 13, 18, 23, 61, 69, 128, 131, 135, 187, 207, 216, 217
Brick....9, 187
Bridgeport.... 186
Brightbill Bros.... 195
Brown, J..... 178
Brown, George M..... 70
Brownstown....135, 196
Brunell cited....26, 28
Bryozoa.... 64
Buchanan.... 41
Buckeye.... 165
Buckwheat, production of.... 163
Bullock, B. E.....75, 175
Bush Nelson.... 61
Butler, M..... 98

C.

Calamites, occurrence of.... 29
Calcite ...9, 26, 42, 80, 89, 188, 198, 203, 208, 212, 219
Calcium carbonate. See CALCITE, TRAVERTINE, TUFA and ANALYSES....42, 182, 188
Calcium sulphate. (See ANHYDRITE, GYPSUM and ANALYSES.)
Caldwell Thomas.... 86
Campbell Charles.... 195
Canada. See ONTARIO.... 12
Canandaigua.... 184
Carbonaceous matter. (See also BITUMINOUS)....18, 67, 81, 89, 94, 95
Carleton....24, 108
Carman, Louis.... 78
Carr, George.... 99
Cartwright.... 92
Cass.... 3, 136
Caudagalli grit.... 36
Caustic soda. (See SODA ASH).... 15
Cavern fauna.... 117
Celery, soil for.... 172
Celestite....9, 80, 208, 209, 212, 219
Cement materials....180, 183
Chalybeate springs.... 213
Chamberlin, T. C..... 129
Champlain epoch.... 132
Chara.... 199
Chautauqua County.... 147
Chattermarks.... 129

Chemung 28
Cherry 165
Chert 41, 76, 77, 82, 90, 97, 129, 216, 217, 219
Chestnut 164, 165
Christiancy, Judge J. P. 71, 160
  Quarries 37, 75, 178
Church & Co. 16, 201
Cincinnati anticline 74, 191
Cinnebar 215
Claims, French 119
  (see number of claims and names of owners.)
  21 22
  64 94
  65 96
  88 96
  160 198
  161 200
  230 61
  275 53
  408 53
  422 200
  428 83
  436 98
  472 196
  484 54
  493 54
  494 53
  498 .... 61, 95, 97
  516 82
  520 200
  521 200
  528 23
  529 .... 23, 93
  530 23
  531 23
  532 61
  538 61
  653 113
  673 198
  683 84
  685 .... 83, 84, 198
Clarke, J. B., cited 29, 30, 31, 37, 44, 227
Clay 19, 20, 24, 39, 94
  uses of 152, 154, 183, 188, 215
Cleveland shales 25, 28
  Moraine 134, 143
Cliff, limestone. See DUNDEE 36
Climate 101, 104, 105, 160, 163, 194
Clover 162, 172
Coal 126
Concretions 26
Cone Station, Elevation of 108
Cone-in-cone " structure 27
Conglomerate 40, 48
Conocardium 226, 227
Contour lines 106
Conularia 226
Corals 40, 56, 226
Corbin, Byron J. 71
Cordier 48, 49
Corn 163
Corniferous. See CHERT and DUNDEE LIMESTONE.
Cosgroy, J. 119
Cotton wood 165
Cousino, Peter, misprinted Cushino 199
Cousino, S. B. 98
Cowles, W. H. 57, 187
Cramer, W. D. 16
Cranberry marsh 156
Crayfish, Effect of, on soil 170
Crapo, S. T. 91
Crinoids 225
Crosby, W. O. Cited 152
Crushing strength of Woolmith stone 175
Crusher for road metal 79, 185
Cummins, Morris, Quarry of 88, 115, 151

D.

Dalton, H. S. 16
Dalmania selenurus 227
Daly, R. A., cited 27
Dana, J. D., cited 49, 216, 217
Daniels quarry 225
Darton, N. H., cited 228
Darwin, Chas., cited 169
Daubrée 58
Dauncy, G. W. 195
Davis, Nelson, quarry of 13, 55, 85, 86, 88
Deep well records 66, 191
Deerfield 201
Defiance, Ohio and moraine 133, 143
Delray 46, 54
Dentons 139
Deposits. See under various formation names.
Detroit, city of 6, 52, 54

Detroit, river 5, 16
  moraine 135, 143
  Stone and Supply Co..47, 185
Detroit and Lima Northern R. R. 75, 79, 109, 176
Devonian = Devonic. See also DUNDEE, SAINT CLAIR and TRAVERSE.18, 25, 28, 37, 192, 228
Diluvium. See also DRIFT and TILL..................11, 12
Dip.............10, 32, 45, 79, 87, 93
Disruptive gouges................ 129
Dobberstein, Augustus, well of... 56
Dogtooth spar. See CALCITE.... 204
Dolomites....46, 47, 49, 51, 59, 67, 68, 70, 73, 92, 94, 97, 99, 176, 180, 183, 186, 206, 212, 219
Donnelly, Peter.................. 204
Doty, E. B....................... 22
Drift. See TILL........19, 31, 38, 44
Dryer........................... 133
Drought effect on wells........... 194
Dunbar, William................. 99
Dundee. See also CORNIFEROUS and UPPER HELDERBERG.
  Chert beds................. 42
  Deep well.........45, 72, 74, 192
  limestone..38, 40, 75, 76, 78, 140, 174, 177, 191, 216, 228
  Quarries......39, 75, 77, 175, 226
  Township (T. 6 S., R. 6 and 7 E.)...9, 19, 20, 24, 31, 36, 37, 38, 71, 108, 113, 139, 152, 162
  Section 8.................. 19
  Section 15.................. 153
  Section 16.................. 153
  Section 18.................. 153
  Section 21.................. 153
  Section 22.................. 153
  Section 25................. 72
  Section 26...............19, 153
  Valley in rock surface...... 122
Duval, Eli P............ 200

E.

Earthworms, effect on soil........ 169
Eaton, Chas. G................... 190
Elder bush........................ 165
Elevations. See ALTITUDES.
Elm............................. 165
Emerson, Mrs. Mary, oölite on farm of..................61, 93
Emmet County............ 14
Eposmite (Epsom salts)....71, 210, 219
Erie ice lobe..................124, 130
  Lake.........8. 13, 106, 108, 208
  marsh.................145, 199
  shale. (See ST. CLAIR SHALES.)
  Township (8 and 9 S., 8 E.) 18, 161, 162, 183, 192, 194 196
  Section 22...........70, 192, 199
  trough of rock surface...... 124
Erigan River.... 123
Eureka Iron & Steel Works...... 15
Everett, Clayton................. 200
Exeter Township (T. 5 S., R. 8 E.)
  Section 1.................. 195
  Section 3..............123, 195
  Section 18.................. 123
  Section 29. See WOOLMITH QUARRIES.............54, 78

F.

Farm products................159, 162
Favosites......................48, 227
Federman, altitude of............ 108
Fenestella.......... 227
Ferguson, Misses J. and N....... 99
Ferretto........................ 126
Findlay, Ohio............133, 134, 191
Fishes................40, 117, 222, 227
Flat Rock.. ....14, 91, 112, 113
Flood plain 11
Foerste, A. F., cited............. 192
Forchhammar.................30, 51
Ford, B. R....................... 34
Forest Beach..18, 105, 114, 139. 140, 141, 143, 154, 171
Fort Wayne, Indiana............. 143
Fossils..34, 92, 93, 97, 99, 137, 220, et seq.
Fracastoro...................... 220
French, W. T., cited............. 164
French occupancy............5, 6, 119
Frenchtown........ 6, 23, 94, 161, 162
  quarries.................... 22
  Twp. (6 and 7 S., R. 8, 9 and 10 E.) See also CLAIMS and RAISIN RIVER.....94, 161, 162
Frey, John...................... 70
Frost, date of................... 101
Fruit culture.............101, 160, 161

Fucus vesiculosus.............. 30

G.

Gaffney, Hugh.................. 175
Gas...............33, 34, 70, 190, 193
Gashing......................... 85
Gasteropods............56, 79, 86 226
Genesee shale. See ST. CLAIR shale...................27, 32
Geodes. See also CHERT......... 11
Geological Surveys; for references to see names of various authors, i.e., for Ohio, ORTON, GILBERT, NEWBERRY, WINCHELL, N. H.; for Michigan, HIGGINS, HOUGHTON, HUBBARD, WINCHELL, A., ROMINGER, LANE; for U. S., IRVING, LEVERETT, TIGHT; for Indiana, DRYER.
Gibraltar......................54, 91
Gilbert, G. K. cited, 5, 140, 141, 146, 147
Gilmore, Q. A. cited.............. 175
Glacial Epoch.............39, 120, 124
Glacial striæ. See STRIÆ........ 129
Glass sand. See SYLVANIA sandstone...9, 11, 55, 84, 86, 88, 186
seams..................... 81
Glœcapsa and Glœthece.......... 65
Goodells......................... 140
Grade of county and railroads. See ALTITUDE............ 106
Grafton, altitude of.............. 108
Grape wild....................... 160
Grape P. O....53, 56, 101, 104, 113, 176
Gravel................19, 20, 110, 153
Grassmere Beaches...141, 143, 154, 171
Great Salt Lake................64, 66
Great Sulphur Springs (near Erie) 199
Greening Bros.................. 196
Grosse Isle....................91, 135
Guelph dolomite.................. 72
Gypsum..........13, 46, 50, 52, 178, 209

H.

Hadley, Walter K................. 91
Halfway Creek..........114, 131, 146
Halite (salt).................211, 219
Hall, I. R. cited.................. 36
Hall, Edmund..................... 54
Hamilton. See TRAVERSE..14, 22, 23, 27, 31, 186
Harmon, James.................. 196
Harris, E. E...................... 70
Line............................ 6
Ville......................... 140
Haw.............................. 165
Hays............................. 168
Heath............................ 182
Heck, Charles.................... 98
Helderberg strata. See DUNDEE and MONROE beds......14, 37
Heliophyllum..................... 227
Hercules Cement Co.............. 180
Herkimer, Robert C.............. 190
Hershey.......................... 23
Hickory...................164, 165
Higgins, S. W...................9, 137
Highlands of the Hudson, a possible lake barrier.......... 137
Hillsdale County................. 22
Historical notes........3, 112, 147, 160
Hoffman, John................... 82
Hogtooth spar..................9, 204
Holland, Ohio.................... 128
Houghton, Douglas.....9, 10, 187, 207
Hubbard, Bella..9, 10, 11, 23, 128, 130, 137, 138, 157, 158, 180, 186, 200, 207, 214
Hubbard, L. L.................... 15
Hudson river group.........11, 72, 74
Hunter............................ 41
Hunt, T. S...........48, 50, 51, 52, 228
Huron Lake..................135, 137
River. 23, 112, 113, 135, 145
Shale.............13, 14, 25, 28
Township.................. 126
Hydrogen sulphide...194, 199, 212, 213

I.

Ice sheet. See GLACIAL EPOCH and ILLINOIAN, IOWAN and WISCONSIN ice sheet.
Ida quarries....14, 87, 88, 174, 177, 207
Twp. (T. 7 S., R. 7 E.)...18, 19, 20, 21, 54, 108, 122, 161, 162
well deep (Sec. 3).........54, 70
Sec 4....................55, 85
Sec. 15....................... 56
Sec. 16.............. 55, 117
Ilgenfritz Nursery Co............ 157

Illinoian ice sheet....23, 126, 127, 130
Imlay........................... 143
Indian occupation............... 5
Indiana geology referred to. See TIGHT, LEVERETT, TAYLOR...................... 133
Ingersoll, R.................... 153
Inlet creek into Ottawa lake.. 91, 131
Iowan ice sheet..............126, 130
Iron ore and oxide..10, 30, 39, 197, 215
Iron pyrite. See PYRITE.
Irving.......................... 58

J.

Jacobs, Charles.................. 190
Jacobson, cited.................. 41
Jackson County...............22, 183
Jefferson County................ 147
Jasper, conglomerate............ 20
Johnson, cited.................. 158

K.

Kallman. Herman, cited......... 175
Kane, Frank..................... 90
Kelley, W. J.................... 200
Kelley's Island...... ......:. 130, 147
Kettle Point (Lake Huron)........ 28
Kilns. See also LIME and BRICK 91, 175, 178
Kingstone's Mills................ 32
Kirschmeier, G. A., cited......... 76
Knaggs, John.................... 83
Knapp, Christopher............. 20
Kring, S. A....... ....82, 176

L.

Labeau, Richard................. 93
Lake. See other part of names, e. g., HURON, ERIE, WARREN.
Shore R. R...85, 92, 106, 108, 186
Ridge. See BELMORE Beach.
. 10
See also MARL, MARSH and SINK.
Lambertville..........19, 70, 114, 196
Lamellibranchs................56, 226
Lane, A. C....26, 32, 40, 66, 72, 73. 109, 141, 142, 228
LaSalle P. O. Station and township. (T. 7 S., R. 8 and 9 E.) 18. 54, 97, 98, 108, 161, 162, 183
Sec. 20..................... 98
Sec. 29..................... 98
Sec. 32.................. 61, 98
Sec. 33..................... 98
Leipsic Beach........133, 134, 136, 143
Lenawee Co..........3, 22, 25, 137, 201
Junction................... 136
Leonard, O. W................... 189
Leperditia alta........... 43, 80, 225
Lepidodendron 29
Leverett, F.......... 23, 126, 133, 134
Lime. See Kilns.......... 9, 175, 179
Limestone. See also CALCITE, BRECCIATED limestone, and DUNDEE limestone and ANALYSES..9, 11, 12, 13, 15, 22, 26, 33, 39, 40, 48. 112, 179, 181, 182, 184
Lithology and lithographic characters and history
of St. Clair shales 29, 35, 40
of Traverse group........35, 40
of Dundee group............ 40
of Monroe group............ 46
Little Traverse group=Traverse 13, 14, 31, 40
Little Lake..14, 61, 63, 65, 98, 224, 225
Little Sink....14, 96, 114, 174, 207, 208, 224, 225
"Liver Rock," mottled DOLOMITE which see................ 66
Livingstone Co.................. 113
Livonia Twp.................... 137
Loam. See SOIL................. 155
Lockwood, Ezra...... 17, 19, 117, 170
London Twp. T. 5 S., R. 7 E.. 9, 19, 20, 37, 161, 162, 188
Sec. 7...................... 34
Sec. 16..................... 87
Sec. 20..................... 19
Long, John 20
Loranger, C. B................... 50
Lotus bed and house.......... 148, 197
Lower Helderberg. See MONROE and HELDERBERG..13, 14. 15. 44, 48, 225, 227

Lower Pentamerus=Kingston 37, 43
Lucas Co. 128
Lulu P. O. and quarries....14, 55, 78, 87, 88, 108

M.

McCarthy, Jacob 78
McDermott, Prof., cited........... 81
Mackinac...................... 28, 137
McMullen, Samuel.................. 34
McQuarrie quarries 91
Macon River..6, 13, 19, 38, 71, 111, 113, 131, 132, 176, 189
Quarries. See CHRISTIANCY quarries..39, 77, 175, 226
Magnesia. See ANALYSES.. 178, 180
Magnesium carbonate. See DOLOMITE....................... 42
sulphate. See EPSOMITE... 71
Manlius limestone. See MONROE beds.................. 37, 228
Maps............... 7, 10, 16, 17, 137
Maple tree..... .... 164, 165
Marcasite............ 26, 30, 213, 219
Marcellus shale............... 27, 33
Marl 10, 24, 182, 183, 200, 201, 219
Marine vegetation................ 29
Marselli 221
Marshall sandstone........ 13, 22, 23
Maschke, cited.................. 41
Matia 49
Matthes, August G................ 190
Maumee Lake and Beach..133, 135, 137, 138, 143, 153
Maumee (=Miami) **River** and **Valley** 8, 89, 133, 215
Maybee.......................... 108
Medina sandstone................ 73
Megambonia...................... 225
Merista and **Meristella**............ 223
Merrill, Geo. P., cited....... 150
Metal, road....................... 97
Meyers Bros...................... 189
Miami=Maumee.
Michigan Central R. R........... 106, 108, 109, 185, 186
Michigan Stone & Supply Co.....16, 79
Michigan White Sand Co.......... 186
Milan Brick and Tile Manufacturing Co.................... 189
Milan Township (T. 5 S., R. 6 E.) 17, 19, 20, 24, 25, 26, 108, 122, 136, 139, 142, 161, 162 195
Section 1.................. 189
Section 2 ....122, 189
Section 3.............20, 34, 122
Section 4.................19, 122
Section 5. ....34, 164
Section 6 ...19, 109, 136, 164, 195
Section 7 ....122, 164
Section 8 ....122, 164
Section 9.............19, 34, 122
Section 10.................. 214
Section 14.................. 34
Section 17.................. 34
Section 18................34, 122
Section 20................19, 196
Section 21.................. 214
Section 22... 34
Section 23.................. 214
Section 26................34, 214
Section 27.................. 195
Milhahn, F....................... 84
Minerals. (See names of minerals) 203
Mitchell map 7
Modiolopsis dubius............... 224
Mohawk Valley, outlet for lakes.. 137
Molasses, beet sugar..........179, 207
Molluscs 155
Monclova, Ohio 128
Monguagon Township. See TRENTON..............12, 135
Monroe beds....36, 43–74, 122, 174, 216, 222, 228
Monroe brickyard 142, 190
Monroe, City of... 9, 10, 18, 40, 47, 52, 93, 108, 112, 113, 138, 162, 164, 190, 207, 208
Monroe County, general facts...1, 14, 25, 39, 107, 127, 161–164, 183
Monroe marsh.................... 145
Monroe Stone Co.....17, 47, 94, 96, 131, 185, Plate IV
Monroe well.........15, 44, 46, 74, 192
Monroe Township 6 and 7 S., R. 8 and 9 E. (mainly occupied by French claims, see CLAIMS)......... 161, 162, 183
Montgomery, E.................... 116
Moraines.............23, 127, 133–143
Morrison, J. M. 123

Morocco, Station, Alt. of......... 108
Mouillie Creek, marsh and pond.. 145
Muck.............. ....155, 156
Mud cracks....................... 47
Mulberry......................... 165

N.

Namet Cybi...... ....6, 160
Nautilus......................... 227
Navarre, quarries.........61, 174, 216
    Alexander T.........95, 97
    Adeline A.............. 199
    Dennis...............61, 97
    Mary T................ 95
    Patrick................ 97
    Francis................ 6
Neumayr, E., cited....... 49
Newberry, J. S., cited..25, 28, 36, 43, 60
Newport........9, 69, 92, 108, 135, 185
    quarries................ 92
    well.................... 67
New York, comparison with series of.......28, 30, 37, 44, 228
    Geological Survey. See also HALL, CLARKE, SCHUCHERT.
Niagara River.................. 144
    Formation......... 73
Nichols, Christopher...... 198
Nicols, John and well..........84, 86
Nims, C. S....................... 72
Nipissing Great Lake.........144, 147
Nitrogen in soils 166, 167, 168, 172, 173
Noble-Moore well at Monroe...47, 66, 74, plate V.
Nogard well.........71, 72, 74, 75, 77
Nolan, Patrick................. 34
Northwest Territory............. 7
Northville....................... 133
Nucleospira roundata............ 223

O.

Oak............................. 164
Oakland County.................. 137
Oats............................ 162
Ochre 214, 219
Ochsenius....................... 210
O'Conner, M. E.................. 70
Ogle, Geo. A..................... 17
Ohio....8, 22, 31, 38, 45, 73, 74, 186, 191
    Geological Survey. See NEWBERRY, ORTON, WINCHELL, GILBERT.
Oil..... ....32, 39, 190, 193
Ohio Shale. See ST. CLAIR shale. 25, 26, 28
Olentangy shale.................. 31
Onondaga strata............13, 37, 43
Ontario..........20, 23, 26, 33, 186, 191
Onychodus....................... 227
Oolite..11, 13, 14, 46, 51, 60, 63, 65, 66, 79, 83, 84, 86, 93, 97, 99, 206
Oriskany sandstone............14, 60
Orthis......................223, 226
Orthoceras..................... 227
Orton, E......25, 29, 39, 44, 73, 130, 192
Ottawa Indians.................. 6
Ottawa Lake....13, 14, 16, 18, 47, 60, 90, 108, 117, 120, 131, 174, 176, 190, 225
Ottawa Lake Quarries.........89, 132
Otter Creek........13, 61, 114, 197 199
Oxbows.....................112, 113

P.

Palaeolithic man............... 5
Palmer, G. W.................... 123
Papaw........................... 165
Paragon Polishing Powder....... 200
Paracyclas elliptica............ 227
Patrick Quarry... 47
Peat..................10, 24, 156, 157
Pebbles accumulation of. (See BOULDERS)........ 153
Pennock, J. D., cited............ 83
Pentamerus...................... 224
Peppermint...................... 172
Pere Marquette.......98, 108, 109, 186
Petersburg......19, 37, 38, 78, 108, 112
Peters, Chas. G................56, 59
    John.................... 78
Petrolea...................32, 38, 39
Petroleum. (See OIL and GAS... 27
Pewamo channel.............141, 143
Phacops......................... 227
Phillipi, E., cited on dolomite.... 50
Pignut. 165
Plants, fossil.........29, 65, 81, 84, 226
    list of trees............... 165

Plants, of sand ridges. (See also chapter on soils and subsoils)..111, 118, 141, plate XI

Plaster. (See ANHYDRITE and GYPSUM)................... 209

Platyceras........................ 226

Pleistocene=Quaternary......... 72

Pleuronotus enos.... 214

Plomodore, Enos 214

Plum Creek....9, 13, 14, 47, 61, 62, 63, 69, 95, 97, 110, 112, 114, 131, 151, 174, 175, 185, 207, 213, 216, 224

Plymouth, Belmore Beach at..136, 137

Point aux Peaux...23, 61, 93, 128, 130, 131, 144, 207, 208, 216, 217

Point Mouillée.................. 145

Polypora..................... ... 227

Poor farm........................ 107

Poplar (popple)...............164, 165

Population......................3, 7

Pontiac, moraine, near........... 136

Portage, strata............... 28, 33

Port Huron moraine.............. 143

Portland cement. See CEMENT.

Potatoes, production of.......159, 163

Postglacial deposits............. 24

Postglacial disturbance.......... 147

Pottawatomies.................. 6

Potter, F. C., and his well .70, 74, 192

Precipitation..........101 to 105, 164

Presque Isle County............. 14

Proteus.......................... 227

Pterinea Aviculoides............. 225

Pulver, Horace, quarry....... 37, 77

Putnam, R. R.................... 16

Pyrite. See SULPHUR....26, 213, 219

Q.

Quarries. See names of owners and chapters thereon.

Quartz.....................84, 217, 219

Quartzite......................... 58

Quaternary formations. See GLACIAL epoch............... 18

Quicksand........................ 19

Quicklime. See also LIME....... 175

R.

Rabideu, Daniel...............89, 117

Railroads. See also names, viz., ANN Arbor=Toledo and Ann Arbor, DETROIT and Lima Northern, LAKE Shore & Michigan Southern, PERE Marquette=Flint & Pere Marquette, WABASH.............1, 2, 108

Raisin River....6, 9, 16, 38, 82, 83, 94, 96, 108, 110, 112, 145, 160, 186, 196

Raisinville Township (T. 6 and 7 S., R. 7 and 8 E.; this township is mainly covered by French claims. See CLAIMS..14, 24, 44, 53, 60, 122, 151, 161, 162, 175, 208

  Sec. 8................. 72

  Sec. 26..................6, 7, 84

  Sec. 8...................... 72

  Sec. 26........... 84

Raisinville quarries.............. 82

Ramsey...................... 48

Rath, Fritz, and quarries...66, 83, 86

Rea.............................. 108

Redgrave, cited on cements....... 182

Retzia formosa.................. 224

Rhizocarps...................... 29

Rhyncospira formosa............ 224

Ridges. See LAKE, RIDGE and BEACH................... 110

Ridgeway........................ 136

Rivers. See names of.......108 to 111

Road metal...................97, 183

Robinson, Samuel................ 215

Robinson and Taylor............ 82

Rock surface topography......... 120

Rock salt. See HALITE........47, 201

Rockwood town and well..145, 190, 202

  South..........108, 114, 123, 201

Rominger, Carl......14, 27, 28, 36, 43, 86, 87, 116, 186, 222, 225

Ross, DeForrest................. 16

Rothpletz, A. 65

Royal Oak........................ 32

Russell, I. C..................... 64

S.

Saginaw Lake.................. 140

Saint Clair River...............5, 32

Saint Clair County................ 148
  Lake........................ 146
  Shale (Genesee shale)....11, 15, 25, 26, 33, 37, 149, 201
Salina..................13, 52, 72, 228
Saline..........................9, 111
Salt.......................15, 47, 201
Salt springs.....................9, 201
Salt water 193
Samaria, elevation of............ 108
Sand.......20, 24, 58, 59, 77, 81, 92, 105, 139, 152, 153, 166
Sandrock and sandstone....11, 14, 34, 56, 87, 88
Sanford, Charles................. 34
Sarnia........................ 26
Sassafras........................ 165
Saylor, C. F., cited............... 164
Schiavo........................ 221
Schoharie grit................... 36
Schuchert, C...........37, 44, 227, 228
Scofield.....................108, 195
Scratches. See STRIÆ........... 10
Sea water......................41, 49
  weed.........................30, 81
Selenite.............67, 69, 72, 209, 219
Shadbush........................ 165
Shale. See GENESEE, ST. CLAIR & TRAVERSE....12, 27, 33, 48, 70
Shaler, N. S...............167, 170, 215
Sharkey, Edward.............197, 199
Sharks.......................... 40
Sherzer, W. H..................80, 227
Shawnee Spring................. 197
Sibley Quarry. See TRENTON.... 16, 39, 75, 77, 129, 177
Siderite........................ 26
Silica. See ANALYSES........... 41
Silicious dolomite...............90, 92
Silt..........................24, 155
Sink holes....................114–116
Sissung, Henry G. and quarry..93, 131
Slaking of various limes......... 177
Smith, G. F....................16, 218
  Mrs. Lizzie.................. 93
  William................... 221
Smyth, C. H., cited.............. 57
Snails.......................... 155
Snowfall........................ 101
"**Soapstone**"=calcareous shale.33, 34
"**Soda ash**"=sodium bicarbonate 15, 177
Soils.....................149, 157, 160
Sorby, cited...................... 57
Sorter, Catherine................ 198
  Elisha...................... 99
South Bass Island................ 128
Southern Chemical Co............ 176
South Rockwood.... 108, 114, 123, 201
Spada.......................... 221
Spalding flour mill, Rock near.... 78
Servis.......................... 12
Sparks & Allen.................. 72
Spencer J. W.................139, 140
Sphagnum...................157, 198
Spink, E. E...................... 34
Spirorbis........................ 80
Spirifer................ 223, 226, 227
Sporangites..................... 29
Squash, Production of............ 163
Statistics.. 4, 7, 103, 104, 105, 159, 161, 162
Steiner, Elevation of............ 108
Stewart farm..................... 78
Stictopora...................... 227
Stone. See ROAD metal, LIMESTONE, SANDSTONE, QUARRIES, etc.
Stone roads...................... 184
Stony Creek....9, 61, 63, 64, 65, 93, 108
  Point.. 23, 61, 63, 93, 99, 130, 131, 135, 136,-144, 175, 207, 208, 216, 217
  Ridge......... 105, 142, 147, 175
Storms, effect of, on wells........ 195
Stout, Katherine................. 190
Strasburg....................... 108
Striæ..............10, 23, 130, 131, 132
Strobel......................... 56
Strophodonta................ 226, 227
Stromatopora............. 64, 79, 227
Strong, Frank................ 22, 187
Strong, John 16, 190
Strontianite.... 9, 85, 89, 205, 206, 209
Strontium. See also STRONTIANITE and CALCITE.. 85, 179, 307
Stumm, Peter.................... 56
Stylolites........................ 89
Subsoil. See chapters v. and vi.. 152
Sugar beet, Climate and soil for 104, 163, 164, 179, 207
Sullivan, Nora................... 84
Sulphates 26, 30

Sulphuric acid and soil........... 167
Sulphur..80, 194, 197, 200, 208, 212, 219
Island...................... 26
waters................. 212, 213
Sumach...... 165
Summerfield Twp. (T. 7 S., R. 6 E.,) 19, 24, 44, 114, 123, 139, 161, 162, 170, 214
Sec. 4................... 20, 78
Sec. 6 139
Sec. 7 .... 20, 190
Sec. 18.................... 139
Sec. 19...................... 214
Sec. 21...................... 139
Sec. 24......... 54, 156, 157, 200
Sec. 25...................... 214
Sec. 27...................... 20
Sec. 31..................... 78
Sec. 34........... 190
Sec. 36 (T. 6 S., R. 6 E.)..... 107
Sundstrom, K. J.............. 76, 94
Suzore, Peter.................... 94
Swan Creek.................. 9, 114
Sycamore 164
Sylvania........... 13, 24, 55, 87, 140
sandstone (glass sand).. 14, 15, 16, 44, 60, 69, 70, 81, 91, 92, 97, 151, 174, 186, 206, 214, 228

T.

Taft, J. M., well of.............. 195
Tamarack Creek................. 61
Taylor, F. B., cited..127, 134, 136, 161, 146
Temperance.................. 23, 108
Temperatures................105, 163
Tentaculites.......... 227
Tertiary clays................... 12
Thickness of strata..18, 26, 28, 32, 38
Thomas, B. W................... 29
Thornbush...................... 165
Thunder Bay.................... 26
Tile..........................187, 190
Till. See DRIFT, BOULDER, CLAY. 19, 152
Titanic oxide..................... 68
Titles, Indian 6
Todd, Charles................... 195
Toledo............7, 74, 101 to 105, 161
Moraine 135, 143
Toledo & Ann Arbor R. R. See Ann Arbor R. R.
Townships. See locations under names of townships, viz., ASH, BEDFORD, BERLIN, DUNDEE, ERIE, EXETER, FRENCHTOWN, IDA, LA SALLE, LONDON, MILAN, MONROE, RAISINVILLE, SUMMERFIELD and WHITFIELD. Tabulations by townships are on pp. 4, 161, 162
Transportation of drift.....22, 23, 78
Traverse. See HAMILTON and MARCELLUS..15, 31, 33, 35, 37, 40, 122, 149, 191
Trematospira 224
Tremolite.......................9, 207
Trembly, Dr. J. B................ 105
Trenton (Monguagon.) See also SIBLEY QUARRY.......12, 23, 74, 130, 135, 177, 227
Trenton deep wells............45, 201
Trenton limestone......70, 71, 72, 73, 191, 192
Trilobites......................56, 226
Tufa, calcareous...........24, 198, 200, 205, 219
Tully limestone.................. 122
Tymochtee slate...............69, 73
Tyre 136

U.

Ubly.........................136, 138
United States lake survey levels . 107
Geological survey. See GEOLOGICAL survey..107, 177, 186
Bureau of Agriculture...... 184
Upper Helderberg. See DUNDEE beds................13, 14, 15, 36, 60, 228
Upper Monroe beds............... 122
Upper Pentamerus limestone..43, 228
Utica shales....................72, 74

V.

Valleys of present rivers.......... 111
the rock surface............ 121
Valrance, Howard............... 56
Van Akin, Simeon............70, 71

Van Wormer, John.............. 127
Van Wert stage and lakes.....133, 136
Vegetation. See PLANTS........ 40
Vescelius, J. R................... 195
Von Buch......................... 49
Vienna, altitude of............108, 199
Vorster, Edward................ 180
Vosges........................... 58

W.

Wabash R. R..................... 122
Wadsworth, M. E................. 15
Waldecker, Mathias............. 127
Waldheimia...................... 221
Walnut.......... ....164, 165
Warping, post glacial..... 147
Washtenaw County...........122, 127
Warren Lake and Beach.......... 138, 140, 143, 153, 154
Waterlime group. See MONROE beds 43, 44, 60, 72, 180, 225, 228
Water supply..................... 10
Water power..................... 112
Wayne County. See also SIBLEY quarries, TRENTON, WYANDOTTE...3, 31, 122, 137, 138, 139, 196
Weathering.................149, 167
Welsh, Thomas.................. 9
West Sister island................ 128
Wethered, cited.................. 58
Wheat, production of............ 163
White, A. D....................... 12
White quarry (Little Lake)....61, 99
Whitehouse, O., striæ at.......... 128
Whittlesey Lake.....136, 138, 143, 153
Whiteford quarries............... 100
Whiteford Township (T. 8 and 9 S., R. 6 E.)...18, 22, 44, 53, 53, 114, 121, 123, 139, 161, 162, 185
    Section 2.............55, 88, 114
    Section 4.................61, 100
    Section 5.................. 53
Whiteford Township Section 7. 89. 91
    Section 8................89, 117
    Section 10...........89, 117, 119
    Section 11.................. 117
    Section 19................91, 116
    Section 25................61, 100
    Section 27.................. 22
    Section 28................53, 54
    Section 29.................. 53
    Section 32................53, 54
    Section 33.................. 53
Whitfield, R. P..............222,-225
Whitfieldella..................... 223
Wilcox, Byron................... 87
Wilcox, Homer..........177, 180, 183
Wiley, on sugar beet industry. 164, 179, 207
Wilkerson, A..................... 71
Williams, H. S., cited............ 227
Willis, C.......................... 99
Willow Run.................. 55, 97
Winchell, A...12, 13, 22, 23. 25, 26, 31, 36, 43, 101, 118, 128, 130, 172, 175, 180, 186, 214, 216, 217
Winchell, N. H................. 36, 73
Winds, Effect of.................. 154
Wisconsin ice sheet.......... 126, 127
Witchhazel...................... 165
Wolff, Emil, cited................ 158
Woolmith quarries.. 14, 54, 60, 66, 78, 81, 82, 91, 131, 151, 174, 176, 185, 194, 204, 208, 212, 218
Wright, C. E.................... 15
Wyandotte (Indian tribe)......... 6
    City of..... 15, 38, 46, 54, 73, 135

Y.

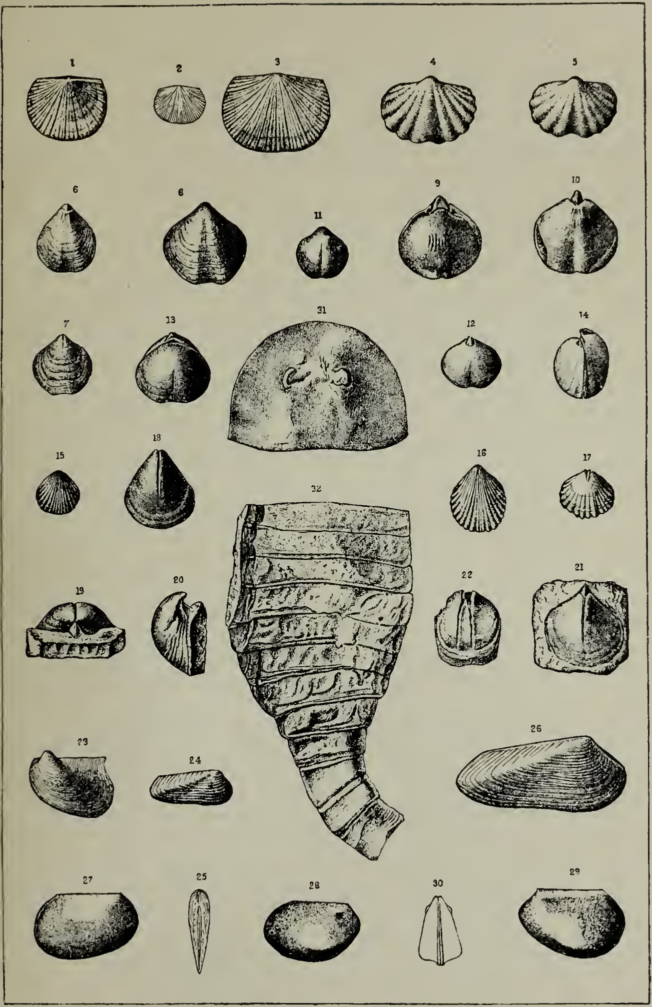
Young, William.................. 195
Young, Stephen.............. 61, 100
Ypsilanti........... 133
Yuma 176

Z.

Zaphrentis....................... 227

DESCRIPTION OF PLATE XVII.

Figs.	1—3.	Streptorhynchus hydraulicum. Whitf.
"	4—5.	Spirifera Vanuxemi. Hall.
"	6—7.	Meristella lævis. Van.
"	8—10.	" bella. Hall.
"	11—14.	Nucleospira rotundata. Whitf.
"	15—16.	Retzia formosa. Hall.
"	17.	Rhynchonella hydraulica. Whitf.
"	18—22.	Pentamerus pes-ovis. Whitf.
"	23.	Pterinea aviculoidea. Hall.
"	24—26.	Goniophora dubia. Hall.
"	27.	Leperditia alta. Conrad.
"	28—30.	" angulifera. Whitf.
"	31—2.	Eurypterus eriensis. Whitf.
		See pp. 223 to 225.



R. P. Whitfield Del

COPIED FROM N. Y. ACAD. OF SCIENCES, VOL. V, PL. V. SILURIAN FOSSILS.

WELLESLEY COLLEGE LIBRARY
3 5002 03596 5131

Science qQE125.
A12 7:1
Geological report on
Monroe County,
Sherzer, W. H.

W. S. George & Co., Printer to the State, pp. 1-15.

1871. Report of the progress of the S. G. S. of M., pamphlet, pp. 1-64.

1873. Vol. 1. Upper Peninsula, 1869-1873. Accompanied by an Atlas of maps. Edition 2,000.

Part I. Iron Bearing Rocks (Economic), T. B. Brooks. Of this an extra edition of 500 with thirteen accompanying atlas plates (1 to 13, No. 2 is misnumbered 11) was issued.

Part II. Copper Bearing Rocks, Raphael Pumpelly (Plates 14, 14a, 15-23 of the atlas accompanying. Chapters IV, VII, VIII are by A. R. Marvine).

Part III. Palæozoic Rocks, Dr. C. Rominger. (Plate 24 of the atlas accompanies. There was an extra edition of 500 dated 1872, without map or index, differing slightly in title page, introduction and paging).

Vol. II. Upper Peninsula. 1869-1873, appendices to Part I, Vol. 1. A Lithology by A. A. Julien, B. Lithology by T. B. Brooks and A. A. Julien, C. Lithology by Charles E. Wright, D. Ore deposits, E. Lithology (Notes by D. Houghton), F. Iron ore dock (by Jacob Houghton and Chas. H. Palmer, with Plate 20), G. Census statistics (1870), H. Magnetic Analyses (by F. B. Jenney), I. Mining laws (by C. D. Lawton), J. Metallurgical qualities by H. B. Tuttle, K. Contortions of Laminæ (by T. B. Brooks).

C. ROMINGER, State Geologist.

1876. Vol. III. Lower Peninsula. 1873-1876, accompanied by a geological map. Edition 2,000.

Part I. Geology of the Lower Peninsula, by C. Rominger.

Appendix A. Observations on the Ontonagon Silver Mining District and the State Quarries of Huron Bay, by C. Rominger. B. Report on the Salt Manufacture of Michigan, by S. S. Garrigues, Ph. D., State Salt Inspector.

Part II. Paleontology. Fossil corals, by C. Rominger (with 55 plates).

1881. Vol. IV. Upper Peninsula. 1878-1880, accompanied by a Geological map. (Edition 2,000.) Part I. Marquette Iron Region. Part II. Menominee Iron Region, by C. Rominger.

See also Vol. V, Part I.

The geological work beginning in Vol. I was continued by Brooks, Pumpelly and Wright in the reports of the Wisconsin Geological Survey.

· Out of print.

C. E. WRIGHT AND M. E. WADSWORTH, State Geologists.

See Vol. II and Vol. V, also the reports of the Commissioners of Mineral Statistics and the following entry:

1893. Report of the State Board of Geological Survey for the years 1891 and 1892, to which are appended exhibits Setting Forth the Expenses of the Survey from its Inception to November, 1892, Exclusive of the Cost of Publication. Also the Reports of Dr. Carl Rominger for the years 1881-2; of Mr. Charles E. Wright for the years 1885-8; of Dr. M. E. Wadsworth for the years 1889, 1890, 1891, 1892, made to the State Board of Geological Survey for the years named; also a Provisional Report by Dr. M. E. Wadsworth, State Geologist, upon the Geology of the Iron, Gold and Copper Districts of Michigan.

L. L. HUBBARD, State Geologist.

1895. Vol. V. Upper Peninsula, 1881-1884; Lower Peninsula, 1885-1893. (Edition 2,500.)

Prefatory Historical Note by L. L. Hubbard.

Part I. Geological Report on the Upper Peninsula of Michigan, exhibiting the progress of work from 1881-1884. Iron and Copper Regions, by C. Rominger, accompanied by a map and two geological cross-sections.

Part II. The geology of Lower Michigan, with reference to deep borings. Edited from notes of C. E. Wright, late State Geologist, by Alfred C. Lane, Assistant State Geologist, with an introduction on the origin of salt, gypsum and petroleum, by Lucius L. Hubbard, and accompanied by seventy-three plates and a map.

1899. Extracts from the annual reports of the State Geologist of Michigan, Lucius L. Hubbard, for the years 1897-1898. (By an error in Lansing this report really contains only the report for 1898. Edition 500.)

Vol. VI. Upper Peninsula, 1893-1897 (edition 954, and 200 of each part privately printed).

Part I. Geological report on Isle Royale, Michigan, by Alfred C. Lane, Assistant State Geologist. Accompanied by 16 plates and 29 figures, including map in cover.

Part II. Keweenaw Point, with particular reference to the felsites and their associated rocks, by Lucius L. Hubbard, State Geologist. Accompanied by 10 plates and 11 figures.

Part II. Appendix. The crystallization of the calcite from the copper mines of Lake Superior, by Charles Palache. Accompanied by six plates (100 extra printed separately).

ALFRED C. LANE, State Geologist.

Coal in Lower Michigan, by Alfred C. Lane, published serially in the Michigan Miner, Vol. I, Nos. 3 to 10, February to September, 1899, (500 reprints).

Annual Report for the year 1899. Michigan Miner, Vol. II, No. 3, February, 1900 (500 reprints stitched in with the following No.).

The Origin, Properties and Uses of Shale, by H. Ries, Special Agent for the State Geological Survey.

Published in the Michigan Miner, Vol. I, No. 12, Vol. II, Nos. 1 and 3 (500 reprints).

The U. S. Survey have published Monographs of the Copper Bearing Rocks of Lake Superior, the Marquette Range, the Penokee Gogebic Range and other publications relative to the Geology of Michigan, for which address the Director, Washington, D. C. Also, Water Resources of the Lower Peninsula of Michigan, by Alfred C. Lane. Water Supply and Irrigation Paper No. 30. 1899.

Lower Michigan Mineral Waters, by Alfred C. Lane, Water Supply and Irrigation Paper No. 31, 1899.

The distribution of the reports of the Commissioner of Mineral Statistics was under the direction of the Board of G. S. from 1877-1883, since when they have been distributed by each Commissioner independently: C. D. Lawton, of Lawton, 1883-91; J. P. Edwards, of Houghton, 1891-93; J. B. Knight, of Norway, 1893-95; George A. Newett, of Ishpeming, 1895-99; Jas. Russell, of Marquette, 1899.